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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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MICRO METALLOGRAPHY ILLUMINATION.

By HENRY M. SAYERS, M.I.E.E.

THE use of the microscope for the examination of metals is now so common in laboratories and works that it might be expected that the manipulative principles would have become a matter of routine. But personal observation in a number of laboratories, and the examination of numerous micro-photographs, shows that in a good many cases the results obtained are not so good as they might be, and that the defects are mostly traceable to lack of understanding of the principles of illumination as applied to opaque objects.

For low-power work, involving the use of nothing higher than a 1-in. or ⅔-in. objective, illumination presents no particular difficulties. A parabolic side reflector serves for oblique illumination, and a microscope cover glass, set at 45 deg., between the objective front and the object, serves for vertical illumination. In either case, the use of a condensing or parallelising lens between the source of light and the reflection, permits of a light concentration of ample intensity for either visual or photographic work.

For higher powers, some form of vertical illumination placed above the objective is necessary. This illuminator takes various forms. The simplest is that of a thin glass set at 45 deg. to the optical axis, receiving light through an aperture cut in the side of the fitting, which forms a part of the microscope tube. This light is partly reflected downwards through the objective on to the specimen. The objective in this case acts as a condenser, concentrating the light upon the specimen. It is obvious that the presence of this reflector leads to considerable diminution of the light intensity received from the source. In the first place, only a part of the beam is reflected downwards, the remainder passes through the glass, and is lost on the black coating of the tube. The converse action takes place on the upward image-forming beams emerging from the objective, part of these are reflected back toward the source of light, only the remainder pass through the glass towards the eyepiece. This happens also when the reflector is between the objective and the object. Therefore, to obtain an image of sufficient intensity for comfortable observation, still more to obtain an image of sufficient intensity and contrast for reasonably short exposures in photographing, the source of light must be of considerable intensity. For photography, it must be of good actinic power. It is usual to provide arc lamps for this work, and nothing better than the positive crater of a continuous current arc is available. Sufficient care is not always taken to adjust the arc in relation to the condensing lens to utilise the crater radiation. In the case of relatively long exposures there is a possibility that the crater may change position owing to the consumption of carbon, to imperfect feeding of the lamp, or to the arc shifting its position. Attention to these points, especially to getting as much of the crater surface as possible directed to the condensing lens, and protecting the arc from draughts, is well repaid by the results.

Another very satisfactory source is the Nernst lamp, with a straight filament. The small diameter of the filament is a drawback, which has to be overcome by the use of a suitable condensing arrangement, giving, in result, a magnified image of the filament as the virtual source of light. A 1-amp. 100-volt lamp gives good results. Photographing will require longer exposures than with an arc lamp. On the other hand, the Nernst lamp consumes much less energy, does not vary, and has no mechanical adjustments to worry about. Unfortunately, Nernst lamps are only made in Germany, and there is now no supply available.

So far as present experience goes, no form of incandescent lamp comes near the arc or Nernst lamp for metallographic purposes. A half-watt closely-coiled straight filament lamp, as supplied for motor-car headlights, give fairly good visual results, but requires long exposures for photography. The Gillingham tungsten arc "Point-o-lite," seems promising, but having had no opportunity of using it, the writer cannot speak from experience.

The greatest difficulty encountered by a beginner, and one which a great many experienced operators never seem to overcome in a satisfactory way, is to obtain an image free from glare and commensurate in its qualities of resolution and definition with the optical power available. This can only be secured by conformity with certain optical principles, which are not difficult to grasp. Of course, if one goes to a first-class maker, and orders a metallographic microscope outfit regardless of cost, the maker will (or should) have designed and disposed the whole outfit, illuminant, condensing system and microscope so that these conditions are automatically fulfilled if instructions are carried out.

But equally good work can be done with a microscope outfit used for other purposes, and, therefore, entailing much less expense, if the operator understands the principles.

The most common trouble is that covered by the word "glare." The origin of this is quite simple. The light from the reflector passing down through the objective is partly reflected from the lenses towards the eyepiece, and superimposed upon the light of the image proper. This reduces its sharpness, contrast, and obliterates fine detail. It is confusing to visual observation, and disastrous to photography. The reflection takes place almost entirely from the convex surfaces of the objective lenses. Such reflection cannot be prevented. The only thing that can be done is to arrange that the reflected light shall be scattered to the sides of the tube, and there absorbed. It may be said in passing, that the prevention of reflection from the tube sides into the eyepiece is of the greatest importance in this use of the microscope. Such reflection can be detected at once by looking down the tube with the eyepiece withdrawn, and the means of prevention by re-blacking, the use of a black diaphragm below the eyepiece, &c., will be obvious.

Now, the reflecting surfaces which cause glare are convex towards the eyepiece. In accordance with the ordinary laws of reflection, therefore, a beam of parallel light will be scattered laterally, excepting for the ray falling normally on the convex surface, which will be reflected normally. A beam of diverging rays will be more scattered with a similar exception. A beam of converging rays will, however, be reflected towards the eyepiece from an appreciable area of the lens, larger or smaller, according to the amount of convergence and the curvature of the lens. These conditions can be detected at once by looking down the tube with the eyepiece withdrawn. If the light falling on the upper objective lens is either parallel or divergent only, a tiny point of light will be seen in the centre line of the objective. If the light is convergent, a larger or smaller image of the source, or of the aperture through which the light enters will be seen. In the latter case, when the eyepiece is inserted, it will be found that this light yields a bright field, which is superimposed upon the image of the object. Hence, to avoid glare, the light meeting the upper objective lens must be either parallel or divergent. Fortunately, this condition is also consistent with the best performance of the objective in regard to resolution of detail and accurate definition.

There is another source of glare which ought to be mentioned. If a "dry" objective of high power is used, this cannot be eliminated. It is due to a part of the light from the specimen being reflected back on to it from the front lens of the objective. As this light is for the most part in a different direction to the true illuminating beam, passing through the objective from the reflector, it has the effect of reducing the contrast in the resultant image. There are, in effect, duplicate images lighted by rays in different directions, superimposed. For all magnifications requiring the use of objectives higher in power than a half-inch, it is preferable to use oil-immersion lenses. One-sixth and one-seventh oil-immersion lenses have been made for metallographic use, but the war seems to have impeded their production in this country.

The conditions for obtaining the full benefit of the optical qualities of the objective employed remain to be considered. Other things being equal, the power of an objective to resolve fine structure and give accurate definition, depends upon what is known as its "numerical aperture," shortly, "N.A." To put it non-technically, this means the solid angle of the beam of light from any point of the object which the objective can grasp and bring to a focus in the image plane. It will be clear at once that the larger the angle of this beam, the brighter will be the resultant image, at the same magnification. It must be taken as a proved fact, both on theoretical grounds and from practical experience, that the limit of fineness of structure which can be resolved by an objective also depends upon this light-grasping power defined as numerical aperture. It may be interesting to say here that as a practical result of this fact, with the materials at present available for lenses and immersion media a keen observer can see everything which the best objectives can reveal with a magnification of 700 diameters. It is true that some extension of this power is available by the use of monochromatic light of short wave length, and of ultra-violet light for photography, with special objectives, but these extensions are hardly practicable at present for the ordinary worker. They open up fields for research.

Now, the objective cannot grasp light which is not reflected or refracted from the object point, which means that the full "N.A." of the objective cannot be used unless the object is illuminated by a beam of approximately equal solid angle. For the more common use of the microscope on transparent objects, such a beam of large angle is provided by a condensing system below the stage. The object is then at the same time in the focus of the condenser, which projects upon it an image of the source of light, and of the objective. With vertical illumination, the objective is also the condenser. To get the best results, then, the objective must at the same time focus upon the object an image of the source of light, and focus into the image which is magnified by the eyepiece the surface of the specimen. The distance above the objective at which the image is formed is fixed by the "tube length" of the microscope. This tube length is generally adjustable within certain limits. It is the case, however, that every high-power objective is designed and corrected for a definite tube length, at which it gives the most perfect image. The maker frequently marks this tube length on the objective, and always states it in his catalogues. It may vary between 160 mm. and 250 mm. For such use as now considered, it is a fixed dimension for any objective, and to get the most perfect image, the objective must be used at that tube length. Practically the tube length is measured between the flange of the objective, which meets the nose piece, and the flange of the eyepiece which meets the body tube.

Now, the distance between an objective and an object, and between the objective and the focussed image of the object are reciprocal, *i.e.*, if the object is put in the place of the image, an image of the object will be formed at its former position. The relative sizes will also be inverted, *e.g.*, if the objective is so focussed as to give an image with a magnification of 100 diameters, it is also so focussed as to produce on the object plane an image of one-hundredth the lineal dimensions of any object placed in the (normal) image plane; and it is not focussed to produce on the object plane an image of anything at a greater or less distance. Hence, for the objective to act in the best possible way as a condenser, *i.e.*, to focus on to the object a reduced image of the source of light, that source must be at the same distance from the objective as the image in the microscope tube.

So the very simple rule is that to get the best results, the source of light must be at tube length distance, measured along the path of the beam, from the objective. This does not mean necessarily that the actual lamp must be at that distance. This may be inconvenient for many reasons. In the case of a Nernst lamp, for example, the width of the filament is so small that under these conditions the image of the filament would give in the field a streak of light too narrow to show a useful extent of the specimen. The condition is fulfilled if the light entering the objective from the reflector is divergent to the same extent as if it were proceeding from a source at tube length distance. This will be the case if the light from the source is condensed into an aerial image at that distance. This aerial image is most conveniently focussed on

an iris diaphragm, placed at tube length distance, which diaphragm can be adjusted to give the necessary intensity of illumination. In the case of a light source of small width or area, this aerial image should be magnified by the condensing lens to give a sufficient width to the image formed by the objective. It may be noted here that the distance between the light source and its magnified image depends upon the amount of magnification and the focal length of the condensing lens. The shorter the focus of the lens, the smaller the distance required for any given magnification. On the other hand, the smaller also is the distance between the source of light and the lens, and, therefore, the greater the heating of the lens. For this reason, a longer focus lens and a greater overall length of bench is needed for an arc lamp than for a Nernst or other filament lamp. For the latter, a condenser of about 2 in. focal length can be safely used. With an arc lamp such a lens would be quickly destroyed. Something like a 6-in. focus lens may be found necessary. This question of distance or length of bench needed, becomes very awkward where space is limited. Some ingenuity can be profitably spent on reducing it by the use of mirrors, &c. Great care is necessary in centering the source to the auxiliary condenser, or an uneven illumination will result.

It will be observed that the best condition for avoiding glare, *i.e.*, the use of a diverging beam, coincides with the best utilisation of the objective as a condenser.

As no image of a light source can be so bright as the light source itself, and a magnified image must, obviously, be much less intense, the best theoretical conditions for brightness of image and shortness of photographic exposure are met by having the source of light itself at the tube distance, and dispensing with all auxiliary lenses between it and the objective. Unfortunately, most of the practicable light sources are too small in area for such direct use. This can be easily realised by remembering that the diminution of the image of the source by the objective acting as a condenser is exactly the same as the magnification of the illuminated part of the object at the image plane. Thus, an arc lamp crater of .125 in. diam. (which corresponds roughly to a 10-ampere arc) would give an image of the same diameter in the image plane. Supposing the eyepiece to have a power of 10 diam., the apparent size of the illuminated field would then be 1.25-in. diam.—seen at the normal vision distance of 10 in., whilst the full microscope field may be from 4 in. to 6 in. diam. This means that only one-tenth of the extent of the object is visible, compared with that of the whole field. Hence, even a 10-ampere arc crater needs magnifying over three diameters to fill a normal field with critical illumination. What happens in ordinary practice is that the light source, actual or virtual, is used at such a distance from the objective that the field is filled with light, unfocussed, and, therefore, far from representing the best illumination conditions. This accounts for the mediocre results generally obtained and accepted because the superiority of the image under the best conditions is not known.

There is one more observation as regards the utilisation of the full "N.A." of the objective. Seeing that metallurgical specimens are approximately plane surfaces, the angle of reflection is equal to the angle of incidence. Consequently the maximum angle of the bundle of rays reflected from any point on the object towards the objective is the same as the angle of the bundle of rays condensed on to the object by the objective considered as a condenser. This means that the resolving power (*i.e.*, the "N.A.") utilised is limited by the diameter of the beam falling on the back lens.

As a general rule, the full "N.A." which an objective can use is realised when two-thirds of the diameter of the back lens is filled by the beam. In vertical illuminator fittings, as generally supplied, the aperture for the entrance of the beam rarely admits so much, even allowing for the divergence between that point and the back lens. Now, the first instinct of a worker who is troubled by glare is to reduce this aperture, and it has the desired effect. But it also reduces resolving power, and produces a spurious thickening of outlines which may amount to a considerable misrepresentation of the structure observed, besides suppressing detail well within the capacity of the objective properly used. Therefore, the regulation of brightness should be effected by the iris diaphragm at or near the virtual light source, and glare avoided by the arrangements set out above. It may be usefully mentioned that a considerably greater brightness of image can be used in photographing than is comfortable to the eye. This can be jduged of on the focussing screen.

It may also be mentioned that the arrangements can be tested on an object of known structure, such as a diatom, which must be mounted in balsam or realgar. For example, Amphipleura pellucida mounted in balsam can be readily resolved into lines, 100,000 per in., with a good 2 mm. oil immersion objective and vertical illumination, better resolved, in fact, than with the same objective by transmitted light. This is as much as can be expected in metallography with our present resources.

Summary.

1. The virtual source of light should be located at tube-length distance from the objective measured along the course of the beam. Or, otherwise expressed, the light falling on the back lens of the objective should diverge as if it came from a source at that distance.

2. The practical test of this condition is that the image of the source of light is sharply focussed on the object at the same time that the object is seen focussed in the field.

3. To obtain the maximum resolving power from the objective, the beam falling on the upper lens from the reflector should approximate two-thirds the diameter of the lens.

4. If the actual light source placed at tube length distances gives too small an image to fill a sufficient proportion of the field for satisfactory observation, a magnified real aerial image of it must be formed at that distance of sufficient area to fill the field.

5. To modify the brightness of the image to suit visual and photographic requirements, use a diaphragm either in the plane of the aerial image or at the auxiliary condenser, not between the objective and the image of the source.

6. For magnifications requiring objectives of shorter focus than ½ in. (12 mm.), use oil immersion objectives.

7. If doubtful of the efficacy of the arrangements, use a suitably mounted diatom of known fineness of structure as a test object.

TEMPLETS, JIGS AND FIXTURES.
No. XVII.

By Joseph Horner.

The illustrations on the opposite page show a lathe fixture designed by the Britannia Engineering Company, of Colchester, for dealing with twin cylinders, the outlines of which are seen in the views. Three sets of operations are included—the boring of the cylinders, Figs. 507 to 510; the boring of the valve cover holes, Figs. 511 and 512; and drilling the holes for the ¼-in. gas taps for the studs in the cylinder tops, Figs. 513 to 515.

For all alike the base is a stout-face plate A, fitted to the lathe spindle. On this, the work-holding boring fixture or cradle B, is carried, Figs. 507 and 509. The base of the cradle fits with a central tongue into a shallow slot that is cut across the centre of the plate A; this permits of adjusting the fixture transversely to bring each bore in turn in alignment with the lathe centre. The fixture is located in each position of the bore centres with tapered pins in two sets of holes *a*. It is secured with bolts *b* that fit in two tee-grooves which go across the plate A. The casting is located within the fixture by means of pads *c*, *c* and *d*, which, taking a bearing on the outside, ensure that the thicknesses of metal—only ⅜ in.—will be alike after boring. Two of these pads *c*, *c*, have lock nuts. They are set diagonally so that castings cannot shift endwise. The third pad *d* bears on both cylinder bodies in opposition to the pressures of *c*, *c*. This pad is carried in the hinged cover C, Figs. 509 and 510, which forms a part of the closed fixture. It is hinged at *e* to the main body B, to be thrown open for the insertion and removal of the castings. These are clamped with the pad *d* and its set screw, and with two others *f*, *f*, in the hinged piece, which take their bearings on the valve faces of the cylinders. The cover C is secured quickly with two eyebolts I, hinged to the body B to be readily swung out of and into position. Rapidity of action is a feature of these detailed fittings.

As the casting and its fixture when in the position shown in Fig. 509, throws a great eccentric load on the lathe spindle, the mass is counterbalanced by the segmental weight D shown in one position in this figure. When the cylinders are moved back for the boring of the second hole, the weight is shifted round with its bolts in the tee slot to a position directly opposite to the cover on the fixture, where the load is greater than it is in the lower part of the fixture. The length of the bolt slot is seen in the face view of the plate A, Fig. 508. The nuts of the bolts which secure the counterweight are sunk below the surface, Fig. 507, for security against accident.

The second fixture, Figs. 511 and 512, is that for boring the valve cover holes. The same base A is used as for the cylinder boring. The casting is reversed from its previous position and is secured with less of elaboration. Instead of the hinged cradle, a plate of cast-iron B, is substituted, fitting with a tongue in the central groove in the base A, and secured with four bolts *a* in the two tee-grooves that traverse the face of A. The face outline of the plate B is seen in Fig. 512. The double cylinder is located on it with two plugs C, C, set on B with dowell pins, and secured each with three cheesehead screws. These plugs fit the holes just bored to 3¾ in. in diameter. The casting, dropped over these is secured with the four clamp plates D, shown in detail to the left of Fig. 512. Each bears on a lug on the back of the cylinder flange. The clamps include their own height packings.

The four valve cover holes are marked 1, 2, 3, 4, in the face view, Fig. 512. These are brought into line with the axis of the lathe, and the fixture B is bolted successively to bring these into the lathe centre and that of its face plate A. This is effected by tapered locating plugs. The plug that occupies its place is shown at *b* (1) for hole 1 (Fig. 1). The other locating holes are marked (2), (3), (4). Those in full lines are in the fixture B, those in dotted outlines are in the plate A. The counterbalance is moved round to new positions to correspond with each re-setting.

For drilling the tapping holes in the cylinder tops the same base A is retained, but another fixture is attached to it (see Figs. 513 and 514) by cheesehead screws sunk in. It comprises a circular plate with one centre plug B to fit each cylinder bore in turn, centralising each bore in the axis of the lathe. The casting is held down with the four clamp plates shown in place in Fig. 514, and separately in Fig. 515. The stud holes are drilled from the tool post of the slide rest.

An example of the chucking of a double cylinder in a fixture on a vertical boring mill by Messrs, George Richards and Co., Limited, of Broadheath, near Manchester, is shown by Figs. 516 to 518, on page 732. In Fig. 516 the cylinder is seen lying in its fixture. It is held and located by its flange attached to a sliding plate as it will be attached to the framing of the car. The main body A of the fixture, of cast-iron, fits with tongues in the grooves of the circular work-table of the machine. It is open at the left hand end to receive the sliding plate that carries the cylinders, this plate being secured by the four clamps and bolts shown. After the cylinder that occupies the centre of the plate has been bored, the other is brought along and set to its centre by means of an end-measuring rod placed between measuring points, one of which is fitted into the body of the fixture, as seen at *a*, Fig. 517, while the other—not shown—is fixed in the sliding work-holding plate.

A large volume of work on the smaller motor cylinders is done on turret lathes with the axis horizontal, as well as on the tables of vertical boring and turning mills, employing turret tool holders on the cross slide. The casting is held in a suitable fixture attached to the face plate, or table, and a battery of tools is schemed to perform the whole of the operations from roughing to finishing bores, faces

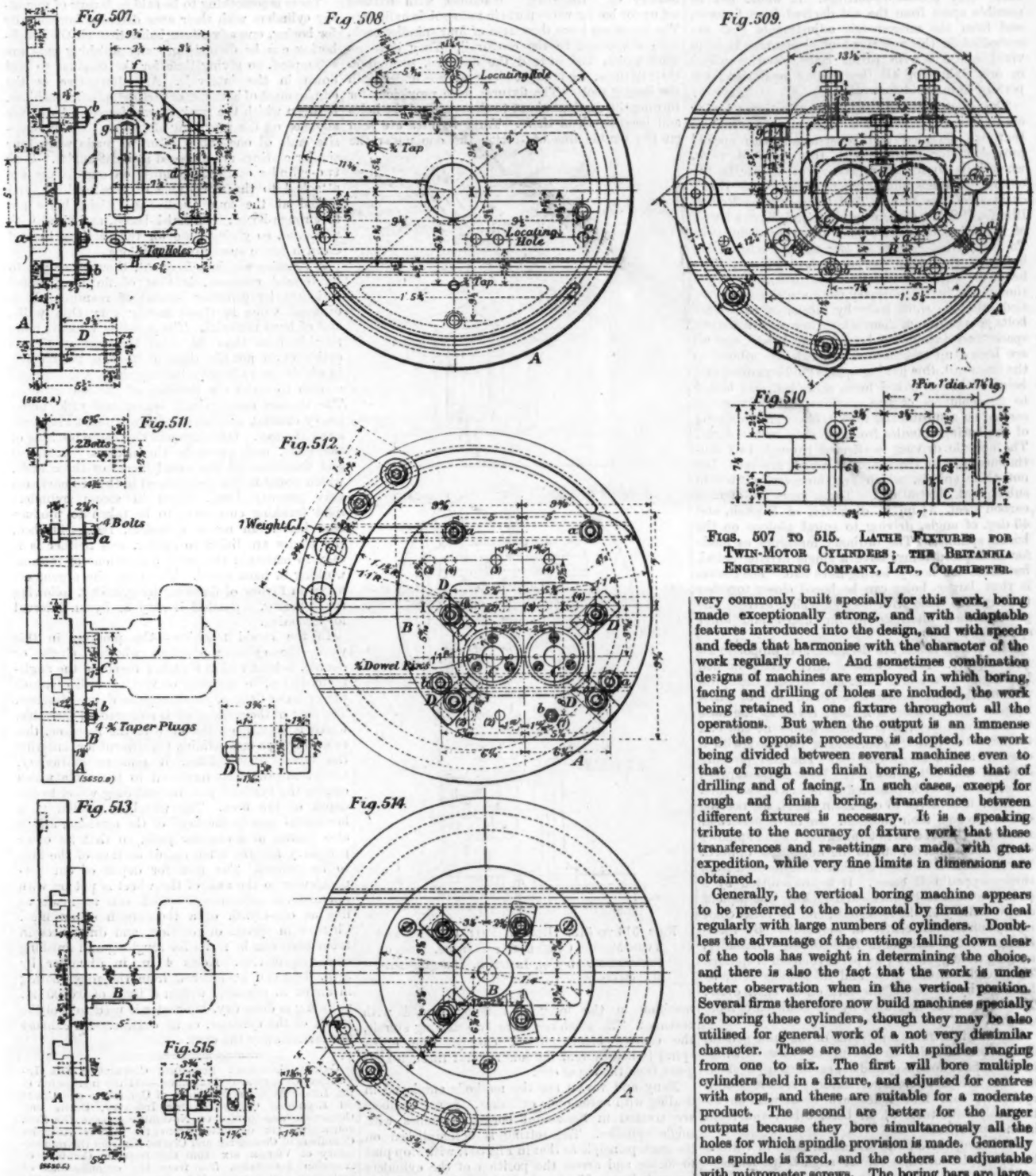
and other details. Although but one piece of tooling can be proceeding at one time, the advantage lies in the multiplication of tools acting in quick succession. And once set-up they will deal with many castings, only having to be dismantled when re-grinding becomes necessary.

The cylinder in Figs. 516 to 518 is dealt with by five tool bars held in a turret on a vertical boring mill. They are, a single round nose tool for rough boring, a double-ended flat tool for finish-boring; and carried in the same bar, a double-ended flat cutter which bell-mouths the cylinder. A double-ended flat tool in the next bar bores the small hole in the cylinder end which receives the plug, and this is followed by a screw tap in the bar succeeding. Another bar following has a single-ended flat cutter which arbors the piston clearance at the lower end of the cylinder. It is necessarily single-ended because it has to be set eccentrically for its insertion and withdrawal through the bore. In the same bar a narrow round-nose cutter takes out the oil groove.

As motor cylinders are generally comparatively small in their bores, the practice has been extended of dealing with them on boring machines of the horizontal type—though more frequently of vertical-spindle design—and very often in addition adopting multiple boring, that is having two or more spindles in simultaneous operation. Machines are very commonly built specially for this work, being made exceptionally strong, and with adaptable features introduced into the design, and with speeds and feeds that harmonise with the character of the work regularly done. And sometimes combination designs of machines are employed in which boring, facing and drilling of holes are included, the work being retained in one fixture throughout all the operations. But when the output is an immense one, the opposite procedure is adopted, the work being divided between several machines even to that of rough and finish boring, besides that of drilling and of facing. In such cases, except for rough and finish boring, transference between different fixtures is necessary. It is a speaking tribute to the accuracy of fixture work that these transferences and re-settings are made with great expedition, while very fine limits in dimensions are obtained.

Generally, the vertical boring machine appears to be preferred to the horizontal by firms who deal regularly with large numbers of cylinders. Doubtless the advantage of the cuttings falling down clear of the tools has weight in determining the choice, and there is also the fact that the work is under better observation when in the vertical position. Several firms therefore now build machines specially for boring these cylinders, though they may be also utilised for general work of a not very dissimilar character. These are made with spindles ranging from one to six. The first will bore multiple cylinders held in a fixture, and adjusted for centres with stops, and these are suitable for a moderate product. The second are better for the larger outputs because they bore simultaneously all the holes for which spindle provision is made. Generally one spindle is fixed, and the others are adjustable with micrometer screws. The boring bars are large, and the boring heads also, leaving only sufficient overhang of the tools for necessary chip clearance. Heavy cutting is therefore practicable.

Single spindle machines are frequently set up as units in a series in order to allow the work to progress from one machine to others for roughing, second-boring, and reaming, which is readily done when the cylinders are held in fixtures. Between



FIGS. 507 TO 515. LATHE FIXTURES FOR TWIN-MOTOR CYLINDERS; THE BRITANNIA ENGINEERING COMPANY, LTD., COLCHESTER.

roughing and finishing the castings may be laid aside to season. It is remarkable that such minute, divisions of tasks should be divided satisfactorily between different machines—divisions which involve very precise re-settings. It would not be possible apart from the aid derived from fixtures, and from the micrometric adjustments that are embodied in the machine-tool elements. It is in vivid contrast with turret lathe practice where in one fixing-up, all the tooling operations are performed in rapid succession.

The view, Fig. 519, page 733, illustrates boring operations on cylinders held in fixtures in machines that are designed and constructed with special provisions for dealing with this class of work, when it is so highly repetitive as to justify the outlay. The machines are one of the "Hole-Hog" designs, of the Moline Tool Company, of Moline, Illinois, U.S.A. Our American friends have a knack of inventing expressive and arresting definitions. To suit cylinders cast *en bloc* these machines are built with two, three, four, or six boring heads. The heads are adjustable for slight variations in centres though not by the ordinary methods, since they are tied into one solid body by means of transverse bolts going through them all. After centres are set, spacers are introduced between the heads, and all are bolted up together. The heads are gibbed to the cross-rail, this having square guiding edges, and being of hollow boxed form, dowelled, and bolted to the columns of the machine. The fixture is carried on a substantial work table. The overhang of the boring spindles from the cross rail is slight. The spindle driving is effected through two continuous spirals, the shafts of which are seen, but not their spirals, which are, however, visible in subsequent illustrations. These gears are of high carbon steel, 3½ in. in diameter, of 5 pitch, and 45 deg. of angle, driving to spiral pinions on the boring spindles. The ordinary machines as made for multiple drilling, have a single driving spiral, but those for heavy boring have two. The reason is that larger holes can be bored closer together than can be done with a single spiral drive. The pinions then alternate in the upper and lower spirals.

The boring heads are designed and proportioned very rigidly. Each includes three bronze-bushed bearings. Two above flank and support the spiral pinion, the one below is tapered, and of great length. The spindle is hollow, bored at the nose to a Morse taper; it is slotted across at the end to drive the boring head, and is provided with a draw-in and a knock-out rod. The end pressure is taken on a ball-thrust face. Wear in the tapered lower bearing is compensated by means of lock nuts. A single belt drives to one main spiral, whence the other receives their rotation. In these particular machines the feed is not imparted to the spindles of the boring heads, but to the work-table upward. This is effected through a chain drive derived from three-stepped belt cones. It is transmitted by a double set of steel pinions and racks. The pinions are cut solidly on the feed shaft, and the racks come nearly under the centre of the table. By interchange of the belt cones 12 feeds are obtainable, ranging from $\frac{1}{64}$ in. to ¼ in. per revolution of spindle. The weight of the table and its load is counterbalanced by cheese-weights hung on the chain drive. The load can be increased by the addition of loose weights.

Fig. 520 illustrates a machine of the same general design occupied in the boring of valve seatings in two sets of double cylinders, castings being stood in the foreground. The fixture receives both cylinders, and four holes are dealt with simultaneously with tools which bore, arbor, and ream in one operation.

For boring valve ports and small holes in various bosses—which often occur at angular positions—machines are designed in which the cross-rail carrying the spindles is fed downwards. These are made primarily to receive four, or six cylinders cast *en bloc*, but can be also used for those cast in pairs, or as triplets. The rail being fed, two sets of cylinders can be mounted independently of each other on the long table, and the operator can be engaged in clamping one set while the other set is being bored. The feed is, as in the other design, through pinions and racks, and the rail and boring heads are counterweighted.

Fig. 521 is a striking illustration of a provision made for systematic mass production. It is a battery of "Hole-Hog" machines with fixtures set up for boring valve ports in automobile cylinders. The machines have three sets of four spindles each, with down-feed to the cross-rail. They have no work-tables, but instead the castings, secured in their fixtures, are brought along on rails underneath the boring tools. The fixtures have provisions for turning the castings about to the angles of the holes and locating them there. Three fixtures are seen on the double line of tracks, the one under the

Fig. 516.

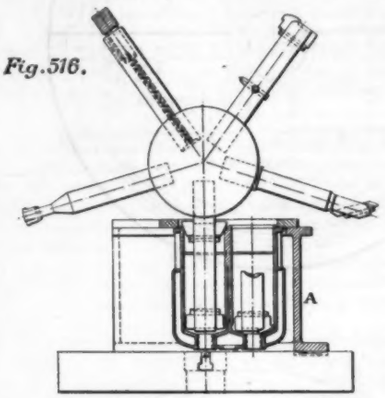


Fig. 517.

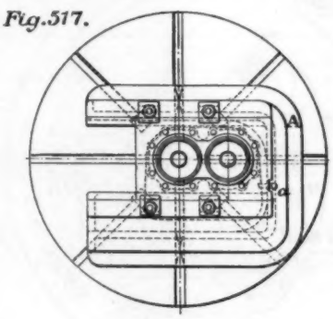
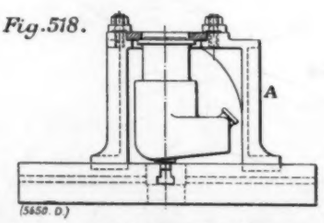


Fig. 518.



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Figs. 516 to 518. Boring Mill Fixture for Twin-Motor Cylinders; Messrs. George Richards and Co., Limited, Broadheath, Manchester.

machine in the foreground being loaded with castings. The machines have two driving spirals, the centres being pitched closely. The upper spiral is belt-driven, the lower spiral through spur gears from the upper one.

Many and varied are the methods employed in dealing with automobile cylinders. Large numbers are treated in horizontal boring machines with single spindles. The setting is accomplished on the same principle as that in Fig. 517, with stop pins to locate and arrest the position of the cylinders for each bore. The method is suitable for double cylinders, but when more than two are cast together the vertical spindle machines are preferable.

In the horizontal machines, fixtures carry either two or four castings on a supplementary table, which is turned through 180 deg. to deal with those on opposite ends of the table, or through 90 deg. if four castings are carried. Using a single spindle, the bores must be treated singly, and the centres set with stops. In cases of this kind it is usual and proper to perform the facing of the flanges with suitable cutters at the same settings, or subsequently to the boring.

There is something to be said in favour of mounting cylinders with their axes disposed horizontally for boring, one advantage being that all the rough-boring can be done before any finishing cuts are attempted, so giving time for the castings to cool down in the intervals. An alternative is the employment of batteries of vertical spindle machines, between which the work is transferred. A distinct advance on the mounting of two castings on opposite ends of one table fixture is made when four similar castings are disposed at right angles. Four two-cylinder castings mounted on one fixture are attached to the work-table of the machine, and locked at the four quadrants. Eight holes are first rough-bored, then finish-bored, and sized with a reamer, so giving time for the castings to cool down between successive operations.

A practice which is frequent, though not yet to be termed common, is that of finishing motor cylinders by grinding instead of reaming. It is of most value in those having very thin walls, and of hard material. The grinding wheel is more reliable here than its rival the reamer. These cylinders are not like those of steam or gas engines in which the walls are relatively thick, and are rigid enough to resist the pressure of the boring tools. The thinner castings will spring and yield under heavy cutting, and hard spots will resist and push away the tool. Openings will also cause hitching of the tools, and generally the necessary hardness and toughness of the metal increases these evils, which would be less pronounced in the ordinary soft gray foundry irons. Even in steam cylinders light finishing cuts have to be taken to produce true bores. In motor cylinders, reamer-finished, the blades are liable to spring, and neither is it easy to maintain the exact dimensions of reamers working in hard metal. These are the arguments urged in favour of finishing by grinding, following rough-boring, separated it may be by an interval for seasoning.

In the Heald machines—the pioneers in this work—the cylinder casting, whethe. single or double, is held within a fixture based on the angle-plate design, to the interior vertical wall of which the cylinder flanges, previously faced, are attached. The base of the angle plate is mounted on the table, which is carried on the knee of the machine, this table having a cross-sliding adjustment for centering the bores. Being fixed, it remains stationary, except for the feed imparted to the table which carries the cylinder past the grinding wheel to the depth of the bore. The wheel is rotated in a horizontal axis in the head of the machine, and is also moved in a circular path, so that its outer periphery has the same radius as that of the hole to be ground. The feed for depth of cut perpendicular to the axis of the wheel is put on with micrometric adjustments which can be made as fine as one-eighth of a thousandth of an inch. Changes in speeds of rotation, and differences in table feeds can be made for roughing and finishing cuts respectively. Holes 4 in. in diameter by 9 in. long can be finished from the rough-boring in about 15 minutes, within a limit of 0·0005 in. Grinding is done dry, but water is used to cool the jacket of the cylinder, or its outside. An exhaust fan carries away the dust.

German-Austrian Economic Committee for Industry, Crafts and Commerce.—At the instigation of the Lower Austrian Chambers of Commerce and Crafts an Economic Committee for Industry, Crafts and Commerce was formed on November 4, says *Die Zeit*, containing six delegates from the Lower Austrian Chambers of Commerce and Crafts, six from the municipality of Vienna, six from the Imperial Combine of Austrian Industries, five from the organisations of craftsmen and hand-workers, five from the mercantile organisations and four from the Association of Banks and Bankers. The new committee resolved to place its services at the disposal of the German-Austrian State Council, and to request that it might be allowed to co-operate in all matters affecting industry, crafts, or commerce. Three sub-committees were formed: (1) For matters concerning industry and crafts; (2) for commercial policy and traffic questions; (3) for financial questions. The function of these sub-committees is to prepare all questions for consideration by the committee.

TEMPLETS, JIGS AND FIXTURES.

(*For Description, see opposite Page.*)

FIG. 519.

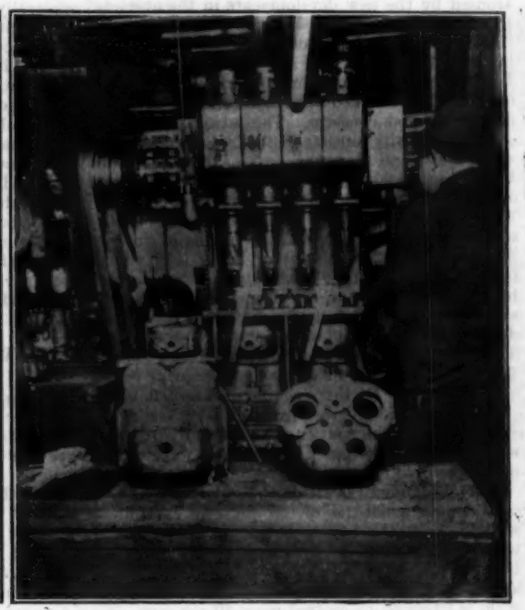


FIG. 520.

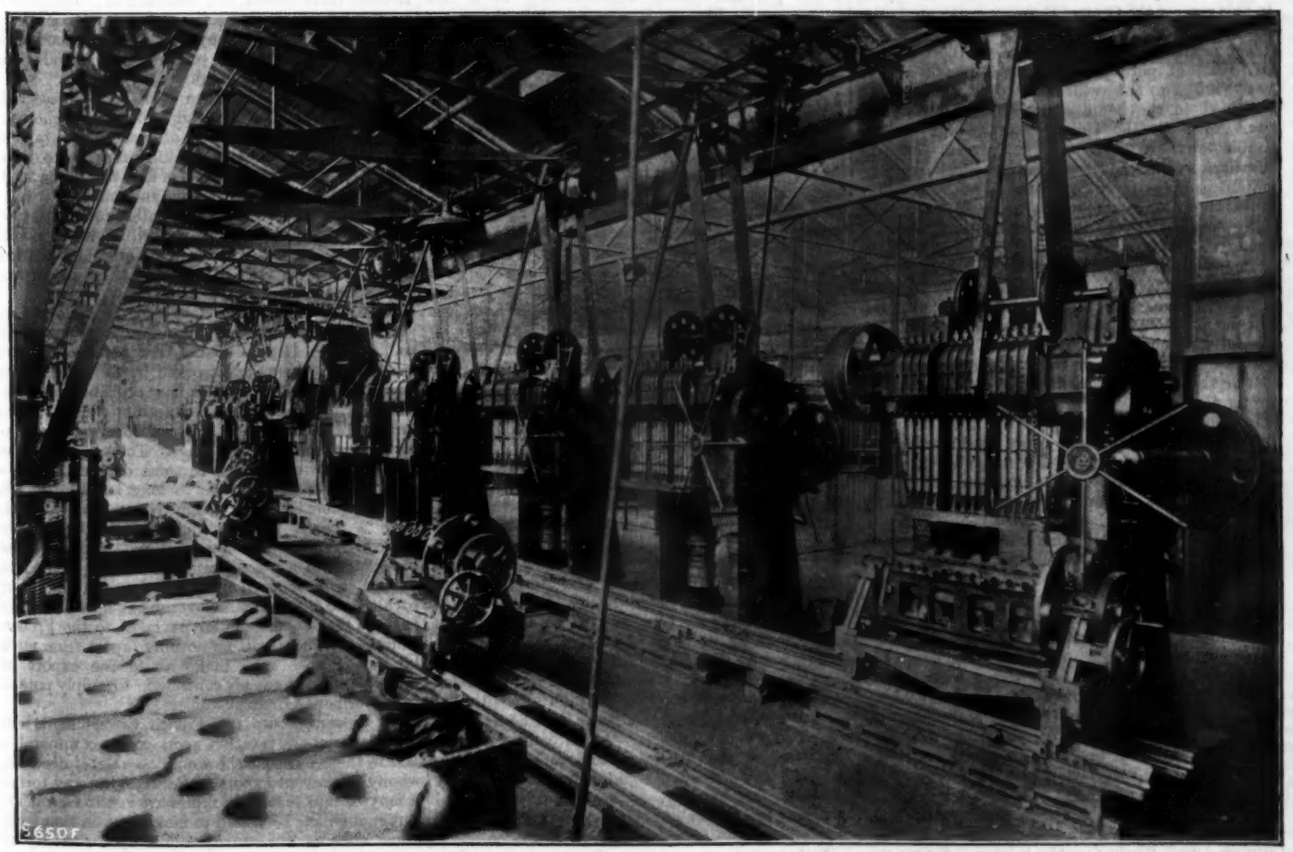


FIG. 521.

FIGS. 519 TO 521. MOTOR CYLINDER FIXTURES DESIGNED FOR USE UNDER "HOLE-HOG" DRILLING AND BORING MACHINES; THE MOLINE TOOL COMPANY, ILLINOIS, U.S.A.

THE POTASH INDUSTRY OF ALSACE.

The severance of Alsace from the German Empire is causing grave apprehensions to the German alkali industry, added to which fears have been aroused by the new developments in the overseas production of chemical manures.

During the last decade or so an important potash industry has been created in the Mülhouse district. In Alsace there are about 100 registered mines of which 80 are looked upon as workable, although not as isolated concerns. The advantage of the Alsatian deposits consists in the fact, that they are very regular and that they, on an average, contain 15 per cent, to 20 per cent. more potash than those of Central Germany, which simplifies the process. Further, these have the advantage of convenient situation for transport and of the vicinity of electric power stations. On the other hand, they suffer from the disadvantage that sulphate, which has become an article of importance in the trade, cannot be manufactured straight off and that the deposits do not extend sufficiently in a horizontal direction to admit of an unlimited number of works. The present number of shafts, completed or commenced, is 17. Of these shafts six are definitely completed, whilst the rest are in different stages of installation or preparation. The vicinity of the war operations has put a stop to the working of most concerns.

The Alsatian works are in a position to supply considerable quantities of 20 per cent. sylvinite straight from the mines, but it is questionable whether this would be advantageous for overseas buyers with the present high rates of freight, even if tonnage were forthcoming. The demand to begin with, is likely to be centred upon 40 per cent., 50 per cent., or still higher per cent. concentrates, because this entails a saving in freight, but it is doubtful whether the works are in a position to supply such material with their present plant. In this respect the Central German works are better placed.

The aggregate alkali output in the best year so far, 1913, of pure potash was 10,100,000 double cwt. (100 kg.) of which 536,000 double cwt. remained in the home country, 2,320,000 double cwt. going to the United States, and 330,000 double cwt. to France. The present efficient Alsatian works, however, cannot even approximately supply these quantities, nor can they probably do it for some time to come, more especially considering the increased demand which is bound to follow after four years of stoppage. In Germany alone the demand is estimated at double what it was in 1913. On account of the increase in available nitrogen products after the war, the demand for potash may somewhat abate, but in the foreign countries, more especially in America, with her cultivations of tobacco, cotton and beet root all requiring potash, there may spring up a very strong demand.

In this connection one must not, however, lose sight of the important point, that Germany is entirely without stocks; delivery cannot keep up with the greatly increased home demand and neutral foreign countries will only receive what is urgently required.

A point which attracts much attention in Germany is the future control of the Mülhouse alkali works, and what price policy the future management will adopt. The upset of the German potash monopoly, more especially as regards the control of prices in the international market, is looked upon as far more grave than the increased production in America, or the supplies from tropical Erythracia or even the Catalonian discoveries. A time may come which will tax the financial and industrial capacity of the different works somewhat severely; and apprehensions of this kind may have helped to steady the active speculation which has been going on in potash concerns.

Four of the large German alkali groups are interested in the Alsatian undertakings, viz.: the German Alkali Works Co., the Wintershall Co., the Gluehauf Sonderhausen Co., and the St. Therese Alkali Works Co. These concerns all have potash works and deposits in various districts, which makes them more independent, nor have the Alsatian possessions meant very much to them so far as profits are concerned, as their yield has been retarded by various causes. In fact several, if not most, of the shafts have up to the present meant a direct loss to the German works, which principally looked to the future for more remunerative results.

It is not an easy matter accurately to state the financial interest which the German works have in the Alsatian undertakings. That of the largest group, the German Alkali Works Co., was booked at some 15,000,000 marks in the year 1915, and has probably since been reduced by writings-off, &c., by say 3,000,000 marks, but the actual value from an industrial standpoint exceeds that figure very materially. With the boom in the alkali kuxes (portions) which prevailed before the German collapse it might even have been put at as much as four times that amount, and notwithstanding recent events, 40,000,000 marks might not be considered excessive.

PRIVATE PROPERTY IN CEDED TERRITORY.

In a letter which appeared in *The Times* for November 28, Brigadier-General F. G. Stone wrote as follows:—"In *The Fortnightly Review* 'Politicus' gives the estimated value of Germany's mineral resources at 237,678,000,000*l*. This amount, of course, will be considerably reduced by the loss of Lorraine."

There is no reason to doubt the figures quoted. It is well known that Germany has large mineral resources, and that those of Lorraine are of enormous value. But is it correct to say that mineral resources of Germany will necessarily be reduced if Lorraine is ceded to France? If the iron mines were the property of the German Government it would doubtless be so. All Government property in a ceded province passes automatically to a new government. But—as is most certainly the case—if these valuable mineral resources of Lorraine are in the hands of German owners, very different considerations apply.

The rules of international law as to the fate of private property are very clearly laid down in standard works. In "Hall's International Law" (7th edition, 1917), the following statement appears in §139: "Of the private property found by a belligerent within the territory of his enemy, property in land and houses, including property in them held by others than their absolute owners, was very early regarded as exempt from appropriation . . . Land being immovable, its fate was necessarily attendant on the ultimate issue of hostilities; an invader could not be reasonably sure of continued possession for himself, nor could he give a firm title to a purchaser and these impressions reacted upon his mind so as to prevent him from feeling justified in asserting the land to be his."

Again, Mr. Coleman Phillipson, in his "Termination of War and Treaties of Peace" (published in 1916), says: "The change of sovereignty through territorial cession cannot affect private rights already vested in individuals or corporations whether municipal or commercial. Private property of every kind remains sacred and inviolable. In this respect the principle of succession has no applicability whatever. Private law, as distinguished from institutional and administrative law, remains valid, and the population of the transferred territory continues to be subject to it and bound by it, until legislative alterations are introduced by the competent law making authority of the cessionary State. The new sovereign possesses no greater power to interfere with the private rights of his new subjects than he has with regard to his old subjects. As he cannot deprive the latter of their titles to real estate, notwithstanding any theory of feudal tenure that may obtain in his country, so he is not empowered to divest the former of their grants of land if lawfully and validly executed before the cession."

With a view to seeing whether the inviolability of private ownership has been recognised in practise, it is useful to look at what has been done in recent times. The treaty which followed upon the Franco-German war is instructive. In the work above quoted ("Hall's International Law," §612) the following statement appears: "In a recent treaty of cession a more liberal treatment was accorded; natives of Alsace and the ceded districts of Lorraine, who chose to retain their French nationality, though compelled to emigrate, were allowed by the Treaty of Frankfort to keep their land property even in the ceded territory." The Preliminary Treaty of Paris which was "done" at Versailles on February 26, 1871, and signed "Bismarck, A. Thiers, and Jules Favre." In Article V of this document, the terms of which, with certain modifications, were incorporated with the "Definitive treaty of peace," subsequently at Frankfort, the following clause was inserted:

"The interests of the inhabitants of the territories ceded by France in everything relating to their commerce and their civil rights shall be regulated in as favourable a manner as possible when the conditions of the definitive peace are settled. A certain time will be fixed during which they will enjoy particular advantages for the disposal of their produce. The German Government will put no obstacle in the way of free emigration by the inhabitants from the ceded territories, and shall take no steps against them affecting their persons or their property."

The same principle—which accords with natural justice—has been observed by Germany in still more recent times. When Heligoland ceased to be English property the private rights of the islanders were not disturbed. No doubt the British Government took care that this should be so; but the point is, that the principle was recognised.

Clause 6 of the agreement between Great Britain and Germany for the cession of Heligoland to Germany, which was signed at Berlin on July 1, 1890, provides: "All rights to property which private persons or existing corporations have acquired in Heligoland, in connection with the British Government are maintained; obligations resulting from them are transferred to His Majesty the Emperor of Germany. It is understood that the above term 'rights to property' includes the right of signalling now enjoyed by Lloyd's."

The rights of fishermen were also preserved. Thus by Clause 7: "The rights of British fishermen with regard to anchorage in all weathers to take in provisions and water, to making repairs, to transhipment of goods, to the sale of fish, and to the landing and drying of nets, remain undisturbed."

The fact that Germany was content to express herself (on paper) bound by this well-known principle of international law must have an important bearing upon what is to take place with regard to private ownership in Alsace and Lorraine.

At any rate it is quite clear that the mine-owners will not be expropriated unless the treaty expressly so provides. It is probable that these mines are owned by Germans and worked by Germans. The vast bulk of their output has probably gone to Germany. There will be nothing apart from express provision in the treaty to prevent the continuance of this state of things. The position of the mineowner will resemble in some degree that of a tenant in possession under a long lease, of which the reversion has been assigned to a new landlord. Such a tenant remains undisturbed. He merely pays his rent to the new landlord. Similarly the proprietors of a potash mine in territory ceded to France will remain in possession. If he paid royalties to the German Government he will merely have to make some similar payment to the French Republic. There will be nothing (apart from such laws as France may make as to the export of minerals) to prevent his continuing to supply potash to his former German customers.

To prevent abuse the French Government will doubtless impose taxation upon exported minerals; and in the sense that she would be able, if need be, wholly to prevent export to Germany on any terms it may be said that these mines are lost to Germany. But enough has been said to make it plain that such a loss does not necessarily follow upon a treaty of cession. This war, however, is unique in recent years in respect of the wilful damage done to private property by our enemies, and it may well be that in default of prompt payment by the German State the private property of German subjects may be

taken and the owners referred to their own Government for compensation. The Peace Conference may recall the saying of the Irishman that reciprocity is a good thing, but it should not be all on one side.

THE TRANSMISSION OF HEAT THROUGH HEAVY BUILDING MATERIALS.

A BULLETIN* recently issued from University College gives a description of certain experiments carried out by the Department of Heating and Ventilating Engineering of University College of the University of London—in particular by Mr. Arthur H. Barker, the Director of the Laboratory; Mr. M. Kinoshita, Assistant; and Messrs. C. H. Avery and F. E. Eustace, research students. We much regret to learn that Mr. Avery was killed at the front in 1917, having volunteered for the Army along with his fellow-student, Mr. Eustace, on the outbreak of the war.

The research has been undertaken on behalf of the Research Committee of the Institution of Heating and Ventilating Engineers, and has been carried out by the aid of grants from the Department of Scientific and Industrial Research.

The objects of the experiments, as stated in the Bulletin, were:—

1. To develop standard methods of testing the heat transmission through thick walls with such accuracy as to ensure that uniform results can always be secured from separate tests of the same wall, and that the causes of variation in results of different tests from the same wall can be investigated.

2. To compare the transmission coefficients for different materials under precisely defined standard conditions, and to verify the applicability of formulae in current use.

3. To measure the degree of variation in the amount of heat actually transmitted in different conditions through walls exposed on one side to the outside atmosphere.

In a short preliminary discussion of heat transmission through a wall it is pointed out that a wall separating two masses of air at different temperatures (1) absorbs heat by contact of air, by radiation, and "sometimes in other ways"; (2) this heat is transmitted by conduction through the wall; and (3) the transmitted heat is given out by three distinct processes:—(*a*) Convection currents; (*b*) evaporation of moisture; (*c*) radiation.

A formula due to Dulong and Péclet, is given for the loss by convection for "still air," showing this to be in proportion to the power 1·233 of the difference in temperature between the surface and the air. An approximate formula for the heat radiated is also given showing that this is proportional to the difference of the fourth powers of the absolute temperatures of the outside of the wall and its surroundings; and it is pointed out that with a difference of only 30 deg. F. the heat given off by radiation would be about 30 per cent. of an average total value. Evaporation is, however, the most difficult factor, and it is practically impossible to deal with this matter otherwise than in a general way.

Having pointed out the great complexity of the problem and in consequence having shown the incompleteness of the ordinary theory in which the resistance to the flow of heat is assumed to depend on three different constant resistances, namely:

(1) From the inner air to the inner surface of the wall, a_1

(2) From the inner to the outer surface of the wall, c/C.

(3) From the latter to the outside air, a_2.

the authors conclude that a complete treatment is impossible and that the ordinary theory is the best that can be developed for practical purposes. Their endeavours are therefore directed towards finding the values of a_1, a_2, C and K, where C is the conductivity of the material of the wall of thickness *c* and K is the overall coefficient of transmission connected with the other constants by the relation

$$1/K = 1/a_1 + 1/a_2 + c/C.$$

which is easily derived.

The general principle of the experiments was to apply heat to a portion of the inside of a wall at such a rate as to keep the inside air temperature, t_i, constant and equal to the room temperature over a long period and to measure the outside air temperature, t_o, at intervals in the same period. Then with the assumptions made above if W is the whole heat supplied in H hours to the area A sq. ft. of the wall $W = K A H (t_i - t_o)$, K being in B.T.U. per sq. ft. per degree Fahr. difference in temperature per hour. Similarly, $W = a_1 A H (t_i - T_i) = a_2 A H (T_o - t_o)$ where T_i and T_o are the inside and outside temperatures of the wall, which are also measured to find a_1 and a_2; and C is given by $W = C A H (T_i - T_o)/c$.

Actually the experiments were carried out by fixing to a portion of the wall under test a chamber, of which the wall is made to form one side, which is otherwise closed, and which, along with suitable instruments, contains a resistance by which means electrical energy is dissipated inside it. The temperature of the air inside the chamber being kept within narrow limits equal to that of the air round the chamber the energy introduced into the chamber will obviously have to pass through the wall. In these conditions the authors state that the stream lines of heat will be perpendicular to the wall surface, but it is clear that this will only be true for one definite distribution of relative temperature on the outer surface of the wall, and as this is not in any way controlled in one set of experiments the necessary distribution of temperature is not likely to exist. It is readily seen that if one side of a wall is kept at a steady temperature while the other side is exposed to the varying conditions of the atmosphere the ideal steady state will never be realised, and therefore only rough determinations of K are possible.

For the purpose of the experiments some special apparatus were found necessary, and for the most part these were designed and made in the laboratory. They display much ingenuity, and in practice yielded excellent performances. The only electric supply available was from the mains of the St. Pancras Corporation. The voltage on these being found to vary by as much as 10 per cent., an automatic regulator was devised by which the voltage applied to the thermostat was kept within 0·5 per cent. of its value. The energy input was measured by means of an Aron watt-hour meter with an automatic recording attachment similar to that used in a recording barometer. The room was heated by gas, and to keep its temperature constant an electrically operated valve was designed to control the gas in a shunt to the main supply by which means the temperature of the air in the room was kept within 0·25 deg. of its mean value. The gas consumed was measured by a meter having a recording apparatus attached, on the general lines of that used with the Aron meter mentioned above. The calorific value of the gas being known, the heat necessary to keep the room at constant temperature is then easily ascertained. No records of this quantity are, however, given. The temperature inside the chamber was maintained equal to that of the air in the room by means of a differential thermostat arranged so that when the temperature inside the chamber fell to 0·25 deg. below the room temperature the current was switched on automatically through the heating coils, and it was similarly cut off when the inside temperature of the air exceeded that of the outside by the same amount. With this device the supply of heat was, of course, intermittent. It was subsequently found possible, by means of another electrically operated thermostat independently to control the temperatures within 0·1 deg. of the mean. Other types of thermostat were also used of which descriptions are given in the Bulletin; to which reference may be made for fuller information.

The tests made belong to three different series, the first of which were made on an old 9-in. brick wall plastered on the inside with ⅜ in. of plaster. The wall was the outside wall of a first floor room; it faced westwards; it was somewhat sheltered by surrounding three-storey buildings, but was otherwise freely exposed to atmosphere. The object of this series of experiments was to obtain mean and extreme values of K under ordinary varying atmospheric conditions. Actually the wall was kept heated continuously for some seven weeks in February-March, 1914, and the data obtained were broken up into thirteen periods varying from 25 to 60 hours during each of which periods the weather conditions were more or less uniform. Throughout, the temperatures of the air in the room and in the chamber were kept between 60 deg. and 61·5 deg. F., and the mean outside temperature varied from about 40 deg. F. to 60 deg. F. From the data thus obtained values of K are found varying from 0·25 to 0·59, the "weighted" mean being 0·40, which is some 22 per cent. greater than the figure generally used. The prevailing weather conditions were recorded and they are given, and it appears from these that wind and rain tend to give higher values for K, while sunshine tends to give lower values. The maximum value 0·59 is associated with an average rainfall of 0·37 in. per day, a south-west wind of 21 miles per hour (No. 5 on the Beaufort scale) and no sunshine; while the minimum value of 0·25 is associated with a rainfall of 0·17 in., a wind velocity of 5 miles per hour (No. 2) and an average sunshine of 5·2 hours per day.

From this series of experiments the authors conclude (1) that the currently accepted coefficients are some 25 per cent. too low if applied to an old wall, and (2) that for such weather conditions as prevailed during the experiments the maximum rate of heat loss is some 45 per cent. above the mean rate. They point out that figures of general applicability could only be obtained as the results of many more experiments made on different types of walls of different ages, in different localities, and extending over very long periods.

The experiments which constitute the second series were made for the purpose of comparing various building materials with regard to the transmission of heat through them when placed in exactly defined and identical constant conditions. This requires the establishment of the "steady state" which means that the experiments must be carried out in the laboratory. For this purpose there were erected two exactly similar walls, 6 ft. sq. by 9 in. thick, of unplastered plain stock brick built with the Flemish bond, exactly facing each other, the inside surfaces being 9 in. apart. Placed centrally between these walls and fixed to each of them was the heating chamber, of square section, and enclosing an area of 4·61 sq. ft. on each wall. Similarly fixed and of similar section, another chamber was arranged enclosing the first. This outer chamber also contained heating coils by which means the temperature of the air in the space between the two chambers was maintained approximately equal to that of the air in the inner chamber. With this arrangement, and by suitably placing the heating coils in the inner chamber, it was found possible to get the distribution of temperature over the inner wall surface enclosed by the inner chamber sensibly similar to that on the outer wall surface directly opposite. Thus the heat generated in the inner chamber passed normally through the walls. To indicate the temperatures over both surfaces of one wall, of the outside air, and of the air in the inner and outer chambers no less than 34 thermo-junctions were employed, those indicating the temperatures of the wall surfaces being cemented to the walls. By means of a commutator-type switch any of these junctions could be put in series with another junction kept constantly at 32 deg. F. and the temperature of the junction was then read on a suitably prepared galvanometer scale. The experiments extended over a period of about 5 months, and readings were only taken after the structure had been heated for about 72 hours by which time it was found that the "steady state" had been approximately reached. The results give a mean value for K of 0·421, the maximum and minimum values being 0·443 and 0·383 respectively. The conductivity is found to be 0·657 and a_1 and a_2 1·45 and 1·84. Since the earlier experiments in this series give considerably higher values of K and λ (the conductivity) than the later ones the conclusion is drawn that this is due to the drying of the wall by constant heating, and therefore that the effect of dampness in a wall may be taken to increase the average emission by as much as 50 per cent. It is also concluded that for a new dry wall the value of K given by Rietschel is about 10 per cent. too low.

In the experiments which constitute the third series one of the brick walls used in Series II was retained, while the other was converted into a 9-in. matchboarded wall. Twenty-six different experiments were made on the combination from which it is found that for the match-boarded wall K is 0·250; the maximum and minimum values being 17 per cent. and 16 per cent. above and below the mean. From this it follows that the resistance to the transmission of heat through a 9-in. brick wall lined with wood ⅞ in. thick with an air space of ¾ in. is about the same as that of a brick wall 21 in. thick.

It is finally concluded from the second and third series of experiments that the ordinary theory of transmission with constant conductivity and constant surface resistances is approximately true—a conclusion of considerable practical importance. The mean values adopted for a plain 9-in. brick wall are K, 0·43; a_1, 1·5; a_2, 1·9; and λ, 0·66. The value of the resistance of a single wood partition ⅞ in. thick is about 0.56.

It appears to us that the accuracy suggested in these figures is much above what is practically useful. We think that exposure to the weather and the deposition of soot and dirt on the wall would sensibly alter the values of a_1, and a_2 and therefore of K. The general object of the experiments is presumably to obtain information which may be used in the design of heating installations. In these the capacity must be such that a proper inside temperature may be maintained irrespective of the outside weather conditions, which may be severe over several days, which means that not mean but extreme values of the coefficients are the more important.

A fourth series of experiments is now being carried out in which only one wall is used; the heating chamber being on the lines of that used in Series I, with the addition of another enclosing chamber to ensure that the heat passes normally through the wall.

* University of London: University College, Department of Heating and Ventilating Engineering. Bulletin No. 2. "Report of Research on Transmission of Heat through Heavy Building Materials." By Arthur H. Barker, B.A., and M. Kinoshita, M.Sc.

4-TON DROP HAMMER AT CREWE WORKS.

We give on Plates LI and LII, published with the present issue, illustrations of a 4-ton drop hammer which has recently been installed at the London and North-Western Railway Works, Crewe. The inception of this hammer arose in the first instance from the fact that owing to many of the trunnion brackets for guns (which were being made in cast steel) were proving defective. It was suggested that a drop-forging should replace the steel casting, but of the firms who were approached in the matter, none were willing to make the attempt. This was in the latter part of 1916, and it was at that time, when the only way out of the difficulty seemed to be that of invoking the aid of our American cousins, that Colonel Ramsden, Director-General of Gun Manufacture, approached Mr. C. J. Bowen Cooke, chief mechanical engineer of the London and North-Western Railway, with a view to ascertaining whether or no the job could be tackled at the company's locomotive works at Crewe.

Although already extensively engaged upon other forms of Government work, and heavily taxed in regard to the ever-increasing demands on locomotive output made by the Traffic Department, the staff of the Locomotive Works were commissioned to use their every endeavour to comply with this further Government request. Dies were accordingly put in hand, and a trial was made, but owing to the fact that the heaviest drop hammer in Crewe works was only 35 cwt., the first steel drop-forgings for the trunnion brackets were not a success, and although the next attempt was "dropped" in best chain iron scrap (and as a forging gave entire satisfaction) the military authorities were not content, insisting that the bracket should be produced in steel.

The difficulty was for the time being overcome with the aid of a 50-cwt. steam hammer, by means of which a steel billet could be roughed down to a shape that would not impose too heavily on the 35-cwt. drop-hammer for giving the finishing blows. In spite of this, however, it was found on the completion of about 1,000 brackets that the 35-cwt. drop-hammer bed was sinking, that it had, in fact, already gone down about 5½ in., showing clearly the impracticability of proceeding further on these lines.

The Ministry of Munitions were accordingly advised of the difficulty that had arisen, the absolute necessity of having a heavier drop-hammer being insisted upon if Colonel Ramsden desired to continue the work. The usual and seemingly inevitable period of "wait and see" was then allowed to elapse, until, finally, in October, 1917, authority was granted for the installation of a 4-ton drop-hammer, and no sooner was this permission obtained than not a moment was lost in putting the work necessary for the installation in hand.

It is here perhaps as well to note the nature of the plant required, and subsidiary to the working of the drop-hammer itself. This subsidiary plant comprises two gas producers, two reheating gas furnaces, and a brick chimney 60 ft. high, a stationary boiler, two 4-ton hand cranes, a 50-cwt. steam hammer, and a suitable "finning" or clipping press. To give some idea of the work thus undertaken by Mr. Cooke at a time of unprecedented stress it may be mentioned that excavations were involved to the extent of 920 cub. yards, the foundations for the 4-ton drop-hammer itself necessitating a cavity 18 ft. deep, and consisting of 240 tons 10 cwt. of granite and 80 tons 10 cwt. of cement, *i.e.*, a total of 321 tons. Structural alterations in the smithy itself also became necessary, new columns and girders having to be erected.

The estimate for carrying out the work complete was 15,100*l*. Excavating was commenced on October 28, 1917, and the foundations completed early in December; the drop-hammer eventually being put into operation on April 14, 1918. It is interesting to note that drop-hammers were introduced originally into Crewe works in 1899, when they were employed solely on small signal stampings.

The 4-ton drop-hammer lately installed is of the well-known type, designed and patented by Messrs. The Brett Patent Lifter Company, of Coventry, and a view of it is given in Fig. 1, on Plate LI. The hammer itself, or "tup," as well as the two upright guides or "legs," are steel castings, and were cast at the Crewe works. The "tup," after machining, weighed 3 tons 19 cwt. 1 qr. The guides, each weighing 3 tons 4 cwt., are fixed in the usual manner, viz., the top ends fit into wrought-iron sockets, and are secured by hardwood taper wedges, the bottom ends are taper, and are maintained in position the exact width of the "tup," with 4-in. set screws, provision thus being made for vertical and lateral adjustment, and for absorbing the vibration.

The base block, supplied by Messrs. Brett, consist of two steel castings, machined on the faces, dovetailed together, and secured by a cotter of suitable dimensions. This arrangement was considered advisable in order to ensure greater facility in transport, and for manœuvring into position, the total weight of the blocks being no less than 58 tons. These blocks rest on a solid concrete foundation as already mentioned, being filled in, and firmly grouted all round and underneath to a depth of 3 ft. 7 in. below floor level with a mixture of liquid cement and granite dust. Substantial steel girders support the overhead cylinders and lifting mechanism, the stroke of the "tup" being regulated by a hand-operated piston valve.

The 50-cwt. steam hammer, seen in Fig. 2, Plate LII. is at present in use for roughing down forgings, partly for acting as a finning clipper, pending the completion of a finning machine capable of coping with the increasing size of the work now being undertaken at Crewe. In connection with the finning machine, which is in course of construction at the Crewe works, it may be stated that the main body casting is of cast steel, and was cast from two 10-ton melting furnaces simultaneously; it weighs approximately 13 tons, or 19 tons prior to the runners being cut away. Exclusive of the pattern-making, the cost of the actual moulding was upwards of 80*l*.; the cooling of the metal took five days; and when released from the sand, the casting was found to be perfect throughout.

The heating furnace used in connection with the 4-ton drop-hammer is shown in Fig. 3, Plate LII. The gas is supplied by two gas producers which are used alternately. They are fitted with an electrically-driven fan supplying the air necessary to mix with the steam, a regular and constant mixture being thus assured, which would not be possible in the case of an ordinary steam-blown producer; this method also affords the advantage of a greater reserve of steam for working the hammers.

Steam is generated by a standard London and North-Western Railway locomotive boiler, taken from stock, and is that of the 5-ft. six-wheels coupled express goods class of engine. The safety valve is set to blow-off at 120 lb. per square inch; the 4-ton drop-hammer works at a pressure of 100 lb., and by means of a reducing valve, the 50-cwt. steam hammer is supplied with steam at a pressure of 60 lb.

With regard to the stamping of the trunnion brackets above mentioned, the present (and satisfactory) method of producing these has been evolved as a result of a very considerable amount of forethought, and experimental work and the various stages adopted are illustrated in Fig. 4. In the first place, a square steel billet, 6 in. thick, is knocked down under the 50-cwt. hammer to a thickness of 4 in. The billet is then reheated and placed under the 4-ton drop-hammer. The effect of a few successive blows between the dies is to knock the billet into a rough trunnion shape, the metal being made to flow upwards into the various recesses of the top die, the width of the trunnion bearing being at this stage of the process about 4½ in., and a fin emerging from between the dies about ⅝ in. thick. The forging is quickly taken back to the steam hammer, which, with one blow, cuts away the fin.

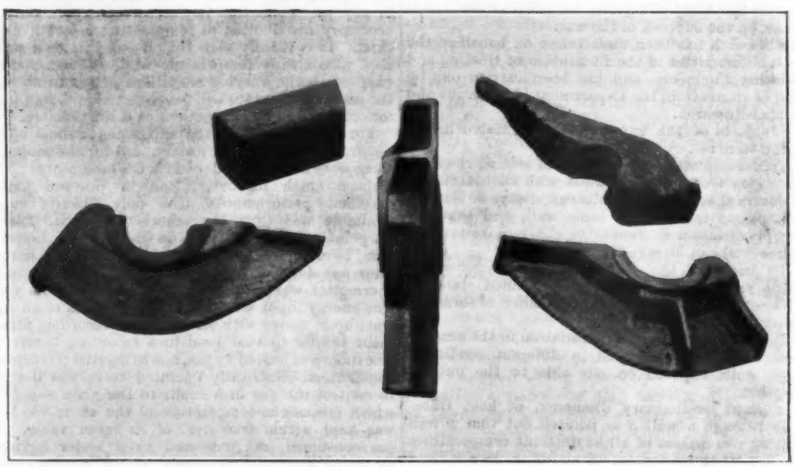


Fig. 4. Stamping Trunnion Brackets.

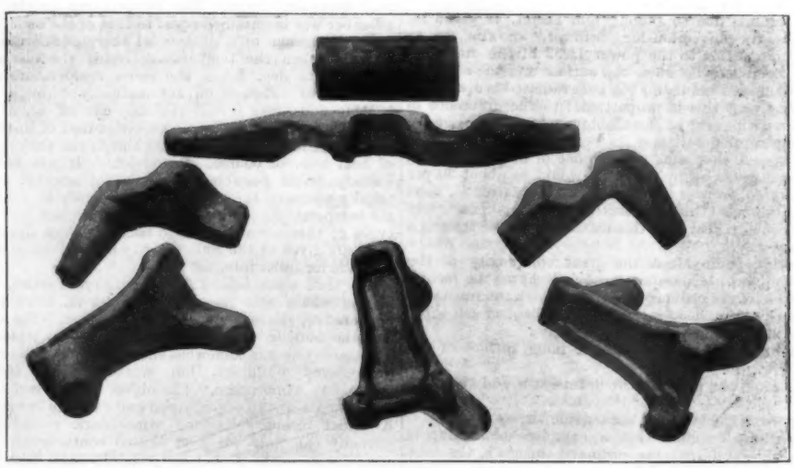


Fig. 5. Stamping Upper Sight Brackets.

A final heat is now effected, and the action of the drop-hammer is to increase the width of the trunnion bearing to the required 4⅝ in., a new fin emerging, but now only ¼ in. thick; as before, the steam hammer once again cuts away the fin, and one final finishing blow under the drop-hammer completes the operations.

As regards the upper sight brackets for certain guns, these brackets were originally produced in steel castings, and it was owing to the fact that as such, a considerable amount of subsequent trouble was experienced, that it was decided to try and make them under the drop-hammer. Here, again, success was only attained in due course as a result of patience and perseverance in experimental work, until finally the

operation as now carried out consists in three stages: (1) Roughing out under a steam hammer, (2) rough stamping under the drop-hammer, (3) finished stamping.

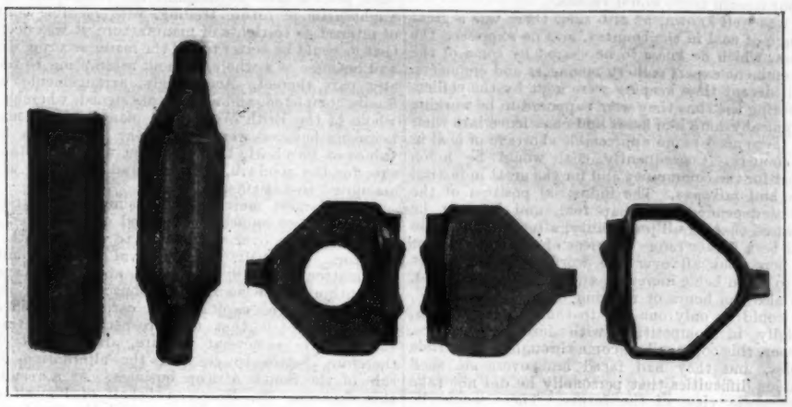


FIG. 6.

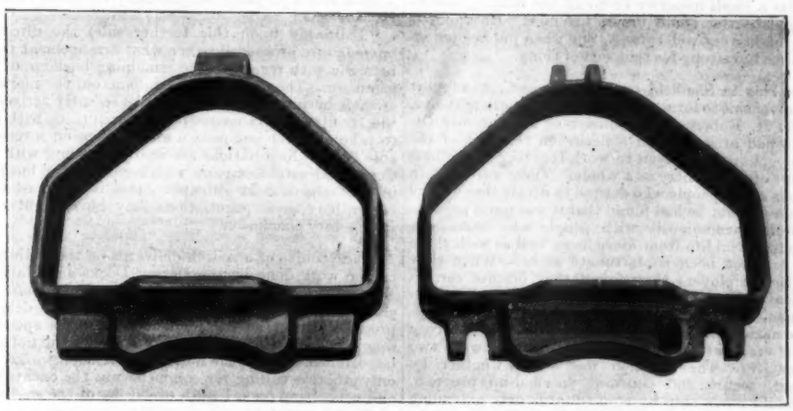


FIG. 7.

FIGS. 6 AND 7. STAMPING FRONT STIFFENING BANDS.

It was found that in the first heat the metal would not flow to the desired shape, but a second heat sufficed to cause the metal to fill the recesses of the dies completely, the various stages of the operations are shown by Fig. 5, on the opposite page.

In the case of the front stiffening band of these same guns, steel castings again failed to satisfy the Army authorities, and once more the newly installed 4-ton drop-hammer was called into requisition.

As will be noticed from the accompanying illustrations, Figs. 6 and 7, it is remarkable to a degree that it should be possible to evolve a band of so delicate an outline as the outcome of a few consecutive 4-ton hammer blows. This nevertheless is the case, and the method adopted is as follows: An oblong steel billet, 6 in. square by 18 in. long is roughed out under the 50-cwt. steam hammer, this is then drop-forged into two rough stampings, the stampings thus roughed out being subsequently dealt with singly under the drop-hammer in a finishing pair of dies. The successive stages of the work are shown by Fig. 6, while Fig. 7 gives two views of a finished band.

As evidence of their evidently genuine appreciation of the successful accomplishment of this work, the Ministry of Munitions forwarded to Mr. Cooke two letters from which we quote the following extracts: "I have to thank you and your staff, on behalf of the Ministry of Munitions, for the excellent work you have done in producing stampings of trunnion brackets—The part in question has, hitherto, been considered almost impossible to produce as a stamping, and the work you have now produced will add materially to the efficiency of this important equipment. I should be glad if this letter could be brought to the notice of your subordinate staff who carried out the work."

"Your previous production of the trunnion bracket in 1916 has been the means of great saving to the State, and it is with great satisfaction that I am able to again congratulate your operating staff on a renewed success in your Stamping Department."

FLUCTUATIONS ON THE GERMAN STOCK EXCHANGES.—To show the effect of the declaration of war, of the industrial activity caused by the war, and of the fears raised by the defeat of the German armies, on the Stock Exchanges of the enemy, we print a list of average quotations over a period of nearly five years:—

—	Dec. 31, 1913.	July 28, 1914.	Dec. 31, 1917.	Aug. 31, 1918.	Sept. 27, 1918.	Oct. 7, 1918.	Nov. 21, 1918.	Nov. 22, 1918.
Group A, 24 concerns..	222	185	278	272	249	197	169	171
Group B, 10 concerns..	203	232	445	442	407	261	210	215

The above figures are the average of each group. Group A comprises Hamburg-America Packet Company, North German Lloyd, Allgemeine Elektricität Gesellschaft, the Bergmann electrical concern, the Bismarck Hütte, the Bochum Union, the German Luxemburg Company, the Gelsenkirchener Company, the Harpen Company, the Laura Hütte, the Lorraine Mining and Iron Company, the Mannesmann Company, the Railway Materials Company, the Caro concern, the Orenstein concern, the Phönix Company, the Rhenish Steel Works, the Rombach Company, the Schuckert concern, the Siemens concern, and the four dye, &c., concerns—the Baden, the Höchst, the Elberfeld and the Treptow aniline concerns. Group B comprises the Daimler Company, the Kleyer Company, the Löire concern, the German Arms Company, the Rhenish Metal Works, the Hirsch concern, the German Rock Oil Company, the German Alkali Works Company, the Westeregeln Company and the Glanzstaff Company.

INDUSTRIAL NOTES

MR. CHURCHILL, Minister of Munitions, has addressed the following message of appreciation to the managers and staff of the firms which have been engaged on the production of Munitions:—

"The achievement of the country in the supply of munitions has completely changed the future aspect of reserve establishments for the manufacture of armaments. No longer can munition supply be looked on as a speciality, since, owing to the adaptability and energy of those recently responsible for the organisation of production it has been proved that the whole engineering capacity of the country can readily adapt itself to such provision.

"It is to be hoped that wars on the large scale are now evils of the past, and that no recrudescence will occur; but in spite of this confident hope, for some time—a long time probably—it will not be safe to neglect the study of fighting weapons. No country must be allowed to advance in this respect while we stand still, and though the provision of such appliances of horror and destruction will in all probability be limited greatly in the future, we must always be abreast of the world in the application of science to war material. If war ever does recur, mechanism will largely supersede muscle, and engineering more than ever will sway the ultimate decision. It is the knowledge of what you have achieved in the engineering shops and factories of the country that permits us to waste the least possible amount of money on what we pray may eventually prove a useless form of production, and to have full confidence that our real reserve is the engineering skill of the country, and that should occasion arise your energy will once more blaze out to supply all that may be required for the security of the Empire.

"The period we are now entering on is one that is full of possibilities and opportunities, and I feel convinced that these will be utilised by you to the full. Much has been learnt by us during the last four years, and the lessons taught by the war will have their effect in many directions. Accuracy of workmanship has become the commonplace of manufacture, waste of energy and materials has been enormously reduced, and I am confident that through the association of the Ministry of Munitions with the engineering talent of the country the phrase "British manufacture" will have acquired a new and even higher meaning than that which justly was assigned to it in the past."

A Research Board has been appointed by the Department of Scientific and Industrial Research and the Medical Research Committee jointly to consider and investigate the relations of hours of labour and of other conditions of employment, including methods of work, to the production of fatigue, having regard both to industrial efficiency and to the preservation of health among the workers.

The duty of the Board will be to initiate, organise and promote by research, grants, or otherwise, investigations in different industries with a view to finding the most favourable hours of labour, spells of work, rest pauses, and other conditions applicable to the various processes according to the nature of the work and its demands on the worker.

For these investigations the Board look forward to receiving the help of employers and workmen in the industries which are studied, and in appropriate cases representatives of both will be invited to serve as temporary members of the Board.

The chairman of the Board is Professor C. S. Sherrington, Sc.D., F.R.S. (Professor of Physiology, University of Oxford); and the secretary is Mr. D. R. Wilson (H.M. Inspector of Factories).

The Board will be glad to receive suggestions as to any problems of the kind described. All communications should be addressed to The Secretary, Industrial Fatigue Research Board, 15, Great George-street, Westminster, S.W. 1.

The recent dispute in the cotton trade, to which we referred in two former issues, received the attention of the Prime Minister, who listened to deputations representing the employers and the operatives. We are glad now to be able to announce that the strike which had broken out among the spinners and card-room operatives was finally settled last week.

A representative meeting of the Operative Spinners' Amalgamation and the Card-room Workers' Amalgamation was held on the 18th inst., when the operatives approved a provisional agreement granting them a 50 per cent. advance on the standard rate of wages. Both the employers and the operatives then met, and the agreement was ratified. The report issued states the following:—

"A joint conference between representatives of the Federation of Master Cotton Spinners' Associations and the Cotton Spinners and Manufacturers' Association, the Operative Spinners' Amalgamation and the Card-room and Blowing-room Operatives' Amalga-

mation, was held in Manchester on December 18, under the chairmanship of Mr. Percy Ashworth. The conference was convened to receive the reports of the decisions of the various organisations on the agreement provisionally come to in London on the wages question. The agreement was unanimously ratified and signed by officials of the respective organisations.

The question as to the date on which work should be resumed was considered, and it was unanimously resolved that the mills should be reopened and the operatives return to work at 8.30 a.m. on December 19. Where, in consequence of the short notice, this may not be possible in some cases, it is strongly urged upon both employers and operatives that work should be resumed at the earliest possible moment."

The Manchester and Salford Association of Patent Cop Winders, Bobbin and Hank Winders, Gassers, Doublers and Reelers, employed in the Manchester doubling mills, received official information yesterday that the members of the association will receive the advance of 50 per cent. on standard rates conceded to the Spinners' and Card-room Amalgamations.

According to *The Manchester Guardian*, a trade correspondent says it is estimated that the cost to employers of the 50 per cent. advance on the wages of operative spinners and card-room workers will amount to about 60,000*l.* per week, and the cost of the weavers' advance about 120,000*l.* per week.

The adjourned fifty-third annual general meeting of the Barrow Hematite Steel Company, Limited, was held in London last week, when Mr. G. Mure Ritchie, the chairman, said that the company had acquired, in conjunction with the Millom and Askam Company, a very large holding of shares in the Ullcoats Mining Company, which was a very successful iron ore mining company in Cumberland, and was the second or third largest producer of iron ore in that county. The iron ore was of pretty high quality, and the acquisition of those shares much improved the position of the Barrow Company in regard to their future supplies of iron ore. In conjunction with the Millom and Askam Company, they had also acquired a number of areas in Cumberland, which their expert advisers considered likely to contain deposits of iron ore. The exploitation of these areas was proceedings as quickly as possible under the prevailing conditions. In addition, they were the largest shareholders in the Beni-Felkrai Iron Ore Mines in Algeria, and their interest in those mines had been of very great value to the company since the war began. With regard to the iron works, their blast furnaces and hot blast stoves were generally being reconstructed on modern lines, while also the blowing power was being augmented. A considerable part of this reconstruction programme had already been finished, though much more remained to be done, and in the result there could not fail to be realised great saving in fuel consumption and lower working costs in other directions. A gas-cleaning plant was also being installed, and it would be of great use in several directions. It would in many ways promote the smooth running of the iron works, and in connection therewith potash would be got from the dust in the blast-furnace gases.

During recent years considerable additions had been made to the steel works. The main part of their steel plant had been of the Bessemer type, which to a large extent, had been replaced in different parts of the country by Siemens open-hearth furnaces. They had already five small Siemens furnaces but they were two small for modern conditions, and about three years ago authority was obtained from the Ministry of Munitions to build an extension of the melting shop and to erect a new steel furnace of large modern dimensions. Shortly afterwards they got authority to build a second furnace, and those two new large Siemens furnaces were now in commission. Before long the directors hoped to extend the melting shop till further, and it was part of their policy gradually to supersede the small old Siemens furnaces, extend the melting shop, and have a sufficient number of large modern steel melting furnaces. Sooner or later there would also come extensive alterations in the steel mills. As to the company's colliery near Barnsley, he said that recently a very careful investigation was made as to the present condition and prospects of that colliery, which produced the very best class of gas coal anywhere in the country. They were satisfied that they had remaining unworked a very large tonnage of coal, and when labour became available they hoped to increase the output from the highest pre-war figure to 750,000 tons per annum—perhaps even nearer 1,000,000 tons—a rate of output which might continue for forty or fifty years.

At the same meeting of the Barrow Hematite Steel Company, Limited, Mr. Mure Ritchie further stated that first one batch and then another of their businesses had been controlled by Government. With every desire to avoid controversial topics, he could not help adding that in his opinion—and he spoke from experience of over twenty-five years of industrial undertakings—if this system of Government control were to continue for a very short number of years longer, it would be equivalent to signing the death-warrant of British industry. It would mean industrial paralysis and consequent decadence of our home industries, while also our foreign trade would vanish.

As was well known, he also said, there was a great shortage of coal in the country, and he expressed the opinion, which he knew to be shared by some of the most eminent expert colliery managers and engineers, that if decent time keeping were kept by the colliers and during the time they were supposed to be working they put anything like heart and conscience into their work there need be no appreciable shortage of coal in this country. Consequently coal would be much cheaper for the community and for the great industrial works and railways. The industrial position of the country depended on cheap fuel, and it must be recognised that, in all probability, after the war there would be a higher range of prices of commodities not only here, but all over the world. Yet, if wages were to go on being increased apparently without end, while also the hours of working were to be reduced, there could be only one end to that state of things, especially in competition with foreign countries. However, this country had come through such terrible troubles, and they had faced and overcome such enormous difficulties that personally he did not take a pessimistic view of the future. There would be difficulties and dangers, but in the long run the common sense of the community would assert itself. He was fully convinced that the British working man, taking him all in all, was every bit as patriotic as any other class, but, unfortunately, he allowed in these particular matters a small minority to do all the talking, and to manipulate the trade union machine. He thought there might very well come a time when public opinion would be too strong for that sort of thing.

Speaking in Sheffield on the 19th inst., in support of a movement to form an Industrial League in that city, Mr. G. H. Roberts, the Minister of Labour said the league had arisen out of a desire on the part of the employers and employed to work together in the best interest of the country as a whole. There were certain sections of the people who desired to divide the country into classes, but he had found that it was quite possible to work harmoniously with people who were in a different social life from himself, as well as with those who had not been so fortunate as he. When they met the employers they found that despite certain political differences they had a great many things in common.

The nation, he added, was on the threshold of a very critical era, and a choice had to be made between two alternatives. The question was as to whether by gradual, secure and constant speeded-up progress, we should move step by step towards ever extending betterment, or whether our people were going to be deluded into the belief that by some violent upheaval they were going to destroy the whole fabric of society and in the course of a few days recreate an entirely new State. If we had industrial unrest and internal strife now that the war was over, it would mark the decline and fall of the British Empire.

The idea of the Industrial League, Mr. Roberts further stated, was that diverse opinions should be subjected to the principle of reason and justice. Co-operation was the spirit of the League. Tremendous changes would have to ensue. There could be no return to pre-war conditions. They were not going back to the state of depressed wages and unsatisfactory living conditions. But they wanted to work together in an atmosphere of friendliness and with a desire for mutual understanding. Whilst the employers would be expected to give concessions in the shape of shorter hours and higher wages, the workers on their part should remember that the responsibility for greater efficiency lay with them.

Speaking at the general meeting of Fraser and Chalmers, Limited, held in London on the 19th inst., Mr. A. W. Tait, the chairman, stated the following:—

"For some time the directors have appreciated that, in order to secure the full development of our manufacturing business, particularly in connection with turbines and turbo-blowers, we should seek an alliance with some company or group in the electrical industry, which would be sufficiently strong to quote for and obtain contracts and orders for large electrical installations both at home and abroad. Towards the end of last year preliminary discussions took place with the General Electric Company, Ltd., as to whether it was possible to arrive at some arrangement with them, so far as our manufacturing business was concerned. The matter received the most careful attention of the board, and it was felt that, if satisfactory arrangements could be made for the sale of the Erith Works and plant, and the greater part of the manufacturing business, but excluding our goodwill and connection with regard to mining machinery, it should be seriously considered. We decided, however, that we should retain our general merchanting business in London, in South Africa, and at our other branches. Arrangements were practically completed with the General Electric Company, Limited upon this basis, but when both parties came to examine the conditions, which might arise in future trading, with possible conflict of interest as to rights of manufacture, it was decided that it would be better to sell the manufacturing works and business as a whole, without attempting to retain any part thereof. Accordingly, arrangements were finally completed, and agreements signed, whereby the whole of the Erith Works and plant and the manufacturing business were sold on the basis of the book values at March 31, 1918, together with a substantial sum for the goodwill, patterns, and drawings, which amounted to £110,000.

"Our largest merchanting business was in South Africa, and we immediately cabled our manager, Mr. Haig, to come over to London to consult with the directors. After Mr. Haig's arrival in this country, the matter was fully discussed, and the prospects of continuing the merchanting business upon some modified basis of capital were carefully considered, but it was felt that the prospects of continued success were somewhat obscure, and that it was, therefore, better to consider the alternative of a sale of the South African business. As a result of this decision, Mr. Haig, on behalf of himself and others, entered into negotiations with the directors for the purchase of the business and assets in South Africa, and an agreement was finally concluded under which the purchasers took over the whole of that portion of the company's business as at June 30, 1918, at a price which provided substantially the book value of those assets.

"Following upon this further sale, the directors immediately proceeded to see what arrangement could be made with regard to the remaining business of the company. They cabled for Mr. Sancton, the manager of their business in Canada, and he recently arrived in this country. Arrangements have been made with him to take over the company's assets there on a reasonable basis. Negotiations are also proceeding with the General Electric Company with regard to the business in Australia and in Singapore, and it is hoped that before long these negotiations may be brought to a satisfactory conclusion."

In the course of a speech delivered on the 19th inst, on the work done by the Mersey Docks and Harbour Board during the year, Sir Helenus Robertson, the chairman, stated that war difficulties had delayed progress except as regarded certain works specially sanctioned by the Government as being of national importance. As for the northern extension works, the only progress calling for comment was the excavating and concreting for a length of 443 ft. of the east wall of the river entrance lock, while some progress had been made with the excavation of the west wall of the lock at its northern end. The steel gates for this lock were in course of construction. They had decided upon the erection of ferro-concrete treble storey sheds, each 100 ft. wide on the Gladstone tongue berth in lieu of the double storey sheds previously authorised.

Special attention had been paid during the year to mechanical appliances for facilitating the rapid handling of cargoes on the dock quays, and further electrically-driven appliances, and a large number of steam cranes, had been supplied which they hoped would materially help them to keep the quays clear. Schemes for the distribution of electrical energy to be supplied by the Corporation had been sanctioned and were being pushed forward. The Board had also authorised the adoption of a comprehensive scheme for the electrification of the dock estate from the Sandon to the Hornby Docks with the view to the extended introduction of electrically-worked mechanical appliances on the dock quays, &c., at a total estimated cost of 123,900*l.* Their railway system to the quays was being increasingly made use of, and about 1,000,000 tons of goods had been dealt with by the Board's locomotives during the year. Additional groups of railway sidings had been laid down at various points, giving a total standage for about 1,165 wagons. As regarded cold storage, the Board had leased the land and premises at the east end of the Alexandra Branch Dock, No. 3, to the Union Cold Storage Company, Limited, for the erection of a cold storage building, which was now proceeding. This would be a material advantage to the port, as it would increase the storage capacity from 5,606,000 cub. ft. to about 8,106,000 cub. ft. The Board had approved of the construction, by Cammell Laird & Co., Limited, of a new entrance, 140 ft. wide, on the site of the present entrance to the company's dock at Tranmere, and also of certain other work by the company.

The attention of the Treasury has been directed to the statement published in some journals of Thursday, December 19, to the effect that a serious situation has

developed owing to the refusal on the part of the Treasury to negotiate with the Workers' Union on a wages question affecting "men employed by 37 Government Departments and engaged on most highly confidential work."

The facts are that the Workers' Union is one of several associations which claims to represent the messengers, cleaners, porters, packers, &c., in the Government Offices in London; and that the Treasury has never refused to negotiate with them in so far as they could show that they had authority to represent any section of these men. It must, however, be understood that in order to avoid disputes on rates of wages between the Treasury or other Government Departments and their employees, the Conciliation and Arbitration Board was established, and it is that body and not the Treasury which gives the final decisions on such questions.

During the past two years several claims have been discussed and settled, either by agreement or by arbitration. One of these claims was for a general minimum wage for the various classes mentioned above (the nature of whose duties differs considerably, but is in no case of a most highly confidential character), and in May last the Conciliation and Arbitration Board for Government employees, whose decision was accepted as final and binding on both parties, heard the claim and rejected it. War bonus increases, however, have been given from time to time to these classes, as to other members of the Civil Service, and from November 1 last, their total remuneration has been 50*s.* a week (with a proportion of higher posts) for a week of 48 hours, with overtime pay at 1*s.* 2*d.* an hour on week days, and 1*s.* 9*d.* an hour on Sundays.

The Workers' Union have now repeated the claim for a general minimum wage, which was adjudicated on in May last, and as the principle of the claim had been definitely rejected by the Arbitration Board the Treasury did not feel justified in re-opening the question, but it is open to the Union to lay the facts before the Conciliation and Arbitration Board, who, if they so desire, may hear the parties again.

AEROPLANES AND AERO-ENGINES.—The Minister of Munitions has suspended until further notice the aeroplanes (Experimental Manufacture) Order, 1917, and the Aero-engines (Experimental Construction) Order, 1918, which prohibited, without a license, the experimental manufacture of any aeroplane, seaplane or part thereof, or any aero-engine. Experimental manufacture means any manufacture not under Government contract, and included preparation of working drawings, but not of general arrangement drawings.

TRADING WITH THE ENEMY ACT.—The Controller of the Foreign Trade Department has issued a new Consolidating List (2° 68*a*), containing the names of over 4,000 persons and firms with whom persons in the United Kingdom are forbidden to trade under the Trading with the Enemy (Statutory List) Proclamation. It is important that every one engaged in foreign trade should realise that he is under an obligation to make himself familiar with the Statutory List, and to observe it in his dealings. Failure in this respect renders him liable to heavy penalties.

THE INDUSTRIAL FATIGUE RESEARCH BOARD.—A Research Board has been appointed by the Department of Scientific and Industrial Research and the Medical Research Committee jointly to consider and investigate the relations of hours of labour and of other conditions of employment, including methods of work, to the production of fatigue, having regard both to industrial efficiency and to the preservation of health among the workers. The duty of the Board will be to initiate, organise and promote by research, grants, or otherwise, investigations in different industries with a view to finding the most favourable hours of labour, spells of work, rest pauses, and other conditions applicable to the various processes according to the nature of the work and its demands on the worker. For these investigations the Board look forward to receiving the help of employers and workmen in the industries which are studied, and in appropriate cases representatives of both will be invited to serve as temporary members of the Board. The Board has been constituted as follows:—Professor C. S. Sherrington, Sc. D., F.R.S. (Professor of Physiology, University of Oxford), *Chairman*; E. L. Collis, Esq., M.B. (Director of Welfare and Health, Ministry of Munitions); Sir Walter Fletcher, K.B.E., M.D., F.R.S. (secretary, Medical Research Committee); W. L. Hichens, Esq. (chairman of Messrs. Cammell Laird and Co., Limited); Edward Hopkinson, Esq., D.Sc. (director of Messrs. Mather & Platt, Manchester); Kenneth Lee, Esq. (director of Messrs. Tootal, Broadhurst Lee Company, Limited); T. M. Legge, Esq., C.B.E., M.D. (H.M. Medical Inspector of Factories); Colonel C. S. Myers, M.D., F.R.S. (Director of the Psychological Laboratory, Cambridge); R. R. Bannatyne, Esq. (Assessor, representing the Home Office); D. R. Wilson, Esq. (H.M. Inspector of Factories), secretary. The Board will be glad to receive suggestions as to any problems of the kind described. All communications should be addressed to: The Secretary, Industrial Fatigue Research Board, 15, Great George-street, Westminster, S.W.1.

THE SOCIETY OF GLASS TECHNOLOGY.

THE twenty-first meeting of the society was held in the Physics Lecture Theatre of the University of Sheffield on Wednesday, December 18. Mr. W. F. J. Wood, B.Sc., F.I.C., the president, was in the chair.

An interesting paper was read by Mr. S. English, M.Sc., on "*An Apparatus for the Accurate Calibration of Burette Tubes.*" Before explaining the process of calibrating a burette, Mr. English gave a demonstration of the method, of which an account has already appeared in the Journal, for calibrating pipettes rapidly and accurately. The method employed for the burette is based on that for the pipette, since it involves the use of a standardised pipette of precisely known volume and time of drainage. Mercury, however, is used instead of water to fill the burette, and the standard pipette into which it drains, in order to calibrate it under the same conditions of ordinary use, water is placed above the mercury level in the burette. This meniscus is viewed through a telescope attached to a cathetometer, and, by an ingenious arrangement, a needle is made to produce a mark on the burette precisely at the level of the meniscus. The author stated that a burette could be calibrated in 5 minutes, and the accuracy was far greater than was usually observed in calibrating these instruments.

In the discussion which followed, the president and Mr. V. Stott took part and Mr. English replied.

Dr. Turner also gave an address on "*Bottle Glass and Glass Bottle Manufacture.*" He stated that his remarks were to be confined largely to the two points, quality and quantity in glass bottle production. In regard to quality he pointed out that it was useless to produce a bottle if the glass of which it was made was unsuitable for contact with the material it was intended to hold.

Medical bottles in particular should be subjected to tests in order to ascertain that they conformed to a certain standard. One test was suggested in which solutions of the alkaloids and mercury solutions were kept in contact with the bottle for 24 hours and the absence or production of a sediment noted. The results of heating a number of different types of bottle in contact with water and steam under pressure were also described and tabulated, and emphasis was laid on the necessity of avoiding excessive use of soda ash in melts. In the case of bottles made from sand, soda ash and lime spar, it was pointed out that lime spar should not fall below 7 per cent. or 8 per cent. of the batch mixture, otherwise the glass was acted on by water to a marked extent.

The lecturer also dealt with the problem of workability, whether from the point of view of hand working or machine working. The effect of different constituents present in bottle glass such as silica, soda ash, lime, magnesia and alumina were discussed and described, and the importance of arranging a batch so that the resulting glass should set quickly was emphasised, if production at a rapid rate was desired. The limits of workability for glasses containing sand, and soda with either lime, magnesia or alumina were set out.

The next meeting of the society will be held in Manchester on January 15, 1919, when a paper will be given on the subject of "*Glass Works Costing*," by Mr. Mills, of the Optical Munitions and Glassware Supply Branch of the Ministry of Munitions.

PERSONAL.—Sandycroft, Limited, of 9, Queen-street place, London, E.C. advise us that from the 20th inst. their new London address will be 4, Broad-street-place, London, E.C.2. Their temporary telephone number is London Wall 7144.

HENRY SAXON SNELL PRIZE.—The subject given in 1918 for the essay in the competition for this prize was "Suggestions for Improvements in Apparatus and Appliances for Dealing with House Refuse." Acting upon the advice of the adjudicators, the council of the Sanitary Institute have awarded the prize of fifty guineas and the bronze medal of the Institute to the author of the essay, writing under the motto "Ædile," James Jackson, Superintendent, Refuse Disposal Department, Birmingham.

ORIENTAL RAILWAYS.—The Bank for Oriental Railways, Zürich, is again unable to declare a dividend for last year. A dividend of 5 per cent. was paid for the three years prior to the last two. Last year there was a revenue from the railways of 2,750,000 frs., against a deficit of 590,000 frs. for the preceding year, which also showed a loss of 268,433 frs. on stocks held. Against these debits there was, however, a credit item of 2,750,000 frs. from "sundry debitors," which made it possible to close last year but one without a deficit. For last year there were several items on the debit side, including 47,451 for loss on stocks, further, 132,205 frs. writings off on outstanding account, and 548,201 frs. paid to the guaranteed funds. The latter, which is connected with an arrangement concerning foreign exchanges, is likely to be repaid, partly, at least, when the foreign exchanges again mend. The outcome is a net profit of 129,978 frs., which has been carried forward to the current year. The shares in the Anatolian Railway Company figure for 66,420,000 frs. and 23,870,000 frs. debentures. The shares in the Heidar-Pasha Harbour figures for 9,720,000 frs. The bank's interest in the Marsina-Tarsus-Adana Railway, now amounted to 10,951,000 frs. The various transport companies connected with the bank had, in spite of the war, continued to work satisfactorily, and not only been able to pay the usual dividends, but also seen their way to provide for material writings-off and reserves.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 18th inst., at the Society's Rooms, 70, Victoria-street, Westminster, Sir Napier Shaw, F.R.S., president, in the chair.

A paper was read by Captain C. J. P. Cave, R.E., entitled "*A Cloud Phenomenon.*" On April 15, 1915, a cloud with an approximately straight front was seen approaching South Farnborough from the north-west. The sky had been clear in the morning. The cloud came overhead at 9·33 a.m., after which the sky was overcast; the sunshine record ended abruptly. At all stations in the eastern and south-eastern counties the sunshine record was similar, though the times of cessation of sunshine differed considerably. By comparing the records it was possible to draw lines on a map showing the times when the cloud front was approximately overhead. The 9 a.m. line ran through the Isle of Wight to Southampton, through Hampshire, Berkshire and Middlesex, north-west of London, along the western borders of Suffolk and Essex, through Norfolk to Cromer. At 10 a.m. the cloud front ran over the east end of the Isle of Wight, along the eastern border of Hampshire, through Surrey, south-east of London, through Essex, Suffolk and Norfolk to the sea, some miles north of Yarmouth. At 2 p.m. the cloud front ran from between Pevensey and Bexhill to Westgate. A map shows the travel of the cloud front from 7 a.m. to 3 p.m., and shows that the cloud travelled across the country at about 12 m.p.h.

A paper by Mr. Charles E. P. Brooks, M.Sc., entitled "*Notes on a Meteorological Journal at Wei Hai Wei, kept by Commander A. E. House, 1910 to 1916.*" was also read. Wei Hai Wei is a small British concession in the north of China, and is important as being in a sense the sanatorium of British stations in the North Pacific. It has a cool summer with a moderate rainfall and a dry bracing winter. Meteorological observations were taken by Commander House four times daily, and include pressure, temperature, humidity, rainfall, wind and weather. These have been summarised and discussed, with notes on the relation of the various elements to wind direction, and on the general climatology and possibilities of Wei Hai Wei.

A third paper presented was "*The Annual Symmetrical Variation of Certain Elements with a Note on the Choice of Seasons,*" by Captain E. H. Chapman, R.E. The average lengths of the astronomical day for the calendar months are more symmetrical for the calendar year, January to December, than for a year (i) December to November, or (ii) February to January. The mean monthly temperatures, Midland Counties, are most symmetrical for a year February to January. The mean monthly values of various meteorological elements are symmetrical for the calendar year January to December. Mean weekly temperatures, Midland Counties, are symmetrical for a year commencing with the fifth week of one year and ending with the fourth week of the following year. The method used to show annual symmetry is to draw the first half of the curve forwards and the second half of the curve backwards along the ordinates of the first half, the nearness of the two portions of the curve showing the degree of symmetry. Annual symmetrical variation makes the division of the year into seasons a difficult matter. There is evidence in favour of making March a winter month. The usual meteorological three monthly seasons are too early in the year, while the astronomical seasons are too late. An alternative suggestion of the three monthly seasons, middle of December to middle of March, &c., is put forward.

RESUMPTION OF TRADE WITH BELGIUM.—The Board of Trade call attention to the fact that the restriction imposed by the Trading with the Enemy (Occupied Territory) Proclamation no longer apply to trading with Belgium, and that, consequently, the obligation to obtain a special licence under that proclamation, as well as the requirement to pay the purchase price for goods imported from Belgium into a blocked account in this country are now dispensed with. Imports from Belgium into this country must, however, be accompanied by certificates of origin, issued in the usual form by a British Consular Officer. Imports into and exports from Belgium are further controlled by the requirement of a licence issued by the Belgian authorities, particulars with regard to which can be obtained from the branch of the Department des Affaires Economiques which has been opened at 110, Cannon Street, London, E.C.4.

THE TIMBER TRADE.—The Controller of Timber Supplies announces that he has now completed arrangements for liberating the National Stock of Imported Hardwoods held by the Timber Supplies Department through the usual pre-war trade channels. Brokers throughout the country are in possession of the necessary particulars of the stock, and merchants and manufacturers desirous of purchasing should make application through their usual suppliers. Prices will be revised from month to month, having regard to freight rates and circumstances which may obtain at each period of revision. The Controller of Timber Supplies also announces that he is now prepared to consider applications for permission to purchase fir staves from abroad for shipment to the United Kingdom and to recommend licences for the import of staves so purchased. Applications should be made on the usual forms to the Controller of Timber Supplies (A.C.T.S.5), 80, Newman Street, Oxford Street, W.1. Permits to purchase will only be granted subject to tonnage being arranged through the Timber Supplies Department.

SHIPBUILDING DEVELOPMENT IN THE UNITED STATES AND CANADA.*

By W. R. Gray and Edward F. Clarke, M.I.Mech.E.

Late in 1917 the authors of this paper, who are respectively the manager of and consulting engineer to the North of Ireland Shipbuilding Company, Limited, Londonderry, left Liverpool for New York, for the purpose of making a tour of the principal shipbuilding yards in the United States and Canada. The managing director of this firm, Mr. Trevisa Clarke, had long contemplated a study of American shipbuilding, as the proper preliminary of any new departure in the rapidly-growing shipyard at Londonderry. The object of the visit was twofold. In the first place, it was desired that, before proceeding finally with the important extension necessitated at Londonderry, an exhaustive survey should be made of the principal transatlantic shipyards with a view to incorporating in this scheme improvements which might commend themselves in mechanical appliances and devices generally for saving labour and expediting progress. In the second place, it was considered that a close survey of the present and, as far as could be ascertained, of the prospective position of shipbuilding in America, would obviously, under the circumstances (with which shipbuilders and marine engineers in this country are familiar) be of considerable value in forming an estimate of the future position and prospects of the industry both there and here. Rumours of extensive developments, both immediate and prospective, had been filtering across to these shores from time to time, and it was thought, and not without good reason, that an investigation such as was projected, would be fruitful.

It was not intended that the results of the visit should gain a wider publicity than that of the immediate circle with which the principals of the North of Ireland Shipbuilding Company are identified; but the fact of the authors' visit to the United States having become known, and the interest it aroused, constrained them, in response to an invitation from the council of this Institution, to contribute this paper.

It will be readily understood that a tour covering roughly 9,000 miles, in a country of great distances like America, in the course of which 22 shipyards were visited, provided a vast amount of information which it will be quite impossible to detail fully within the restricted limits of this paper. The authors will endeavour, however, to convey as completely and as concisely as possible a view of the situation as they found it, in the hope that it may prove to be as instructive to others as they themselves found it.

Arriving at New York on October 2, the authors placed themselves unreservedly in the hands of members of Sir John Esplen's firm resident there, from whom they received most valuable advice and assistance, and through whose good offices they had the pleasure of meeting and exchanging views with a large number of prominent men in shipping and shipbuilding circles in New York, as well as a host of principals and leading officials in the American shipbuilding world whom they met subsequently in their travels.

A brief outline of the itinerary mapped out may be of interest. From New York to Boston, Mass.; Boston to Montreal; Montreal to Ottawa; Ottawa to Toronto; thence to Vancouver, B.C., calling at Collingwood, Port Arthur, and Winnipeg, on the way. The establishments at Victoria, B.C., were then inspected; and thence the authors proceeded to Seattle, Portland, San Francisco, Alameda, and Los Angeles. Chicago and Detroit were then visited; returning thence to New York, and subsequently calling at Philadelphia, Chester, Baltimore, Sparrows Point, Washington and Newport News.

The few days the authors permitted themselves to spend in New York, making arrangements for the long journey overland and gathering necessary preliminary information, were full of interest. Naturally, the all-absorbing topic in the circles in which the authors found themselves was the interesting one of shipbuilding, nor was this interest confined to shipbuilding and shipping circles. The newspapers and technical journals were full of it, and the authors soon began to realise that America was preparing to grasp the opportunity of doing big things in shipbuilding, which the exigencies of the situation created by the war had brought within her reach.

From about the end of the second year of the war, when the shortage of tonnage began to make itself felt, and British, allied and neutral shipbuilders were unable to make good the deficiency in time, allied and neutral shipowners were inevitably attracted to America for ships. The orders which flowed westward naturally gave a considerable impetus to the shipbuilding industry there. Moreover, the certainty of the demand continually for some considerable time after the war, encouraged not only those already in the industry to proceed with large and important extensions of their plants, but brought a great many others, principally steel manufacturers and bridge builders, into the arena.

The entry of America into the war early in 1917, and the imperative need for transports, made the shipping position, already becoming alarming owing to the sinkings by mine and unrestricted submarine attack, still more acute; and the American International Shipbuilding Corporation was formed. This in a powerful corporation, backed by a Government which had pledged itself to win the war, was invested with almost unlimited powers to take over ships under construction for allied and neutral owners, and to build up a fleet of transports to the utmost limits of American resources.

The programme mapped out was a large one, and included not only the building of ships, but also the creation of new shipyards. An addition to the world's ocean shipping of 14,715,000 deadweight tons was to be made within three years. This, in a country whose shipbuilding returns up to 1914 were comparatively insignificant, was rather a large commitment. When it is remembered that, in that year, the output was not more than 450,000 tons, the boldness of the programme and the possibility of its fulfilment passes belief.

At all events, the immediate result was to stimulate the industry still further, and to encourage an abundant flow of fresh capital into this promising channel. The authors, in the course of their investigation, and owing to the limited time at their disposal, were only able to touch the fringe of the great array of new shipyards which were springing up on both shores of the North American Continent; but what they saw confirmed them in the opinion that both the enterprise and capital necessary for a far-reaching and immediate expansion of the industry were not by any means wanting.

The American International Shipbuilding Corporation came into existence immediately after the Emergency Fleet Corporation had been formed. This great combination of steel magnates undertook the task of laying down the largest shipbuilding yard in the world, and promised that this would be completed and that 200 ships would be launched from it and commissioned for sea inside of two years. This ambitious project the authors found, on their arrival at New York, was being freely discussed, and they must confess they viewed the prospect of its fulfilment, in the time promised by its promoters, with anything but sanguine expectation. An excursion to Hog Island, undertaken out of curiosity and merely to inspect the site of this great shipyard of 50 ships, was made prior to the authors' departure on their tour of completed shipyards. To say the least, it was surprising to see what had been done within the short space of three weeks, in the preliminary work of excavation and laying out of roads, &c. There was, in the scene of activity which presented itself, much food for thought, and the conviction that great things were going to be accomplished here began to take root in the authors' minds. A return visit, made 10 weeks later, confirmed this first impression; and already this great shipyard is in full swing, and inaugurated as far back as August 5, 1918, its ambitious launching programme. A few facts regarding this gigantic undertaking may be of interest.

The frontage to the river (Delaware) measures roughly 6,000 ft., or well over 1 mile. The yard is divided into five groups of 10 building berths, each of these groups being subdivided into two sections of five, each such section being practically a shipyard in itself, with its own equipment, buildings, management, and workers. Finished steel material is brought here from 60 steel and bridge works, scattered throughout the United States and Canada. The original contract entered into between the International Shipbuilding Corporation and the Emergency Fleet Corporation was for 50 11½ knots, 7,500 tons deadweight cargo vessels; later the contract for 70 15 knots 8,000 tons troop and cargo ships was made; and this year another contract for 60 more of the 7,500 tons vessels was entered into; so that at the present moment, this concern has actually on hand 150 vessels. Three vessels per week will be launched from this great yard; that is to say, three ships per slip per annum. It was subsequently learnt that this was the task every shipbuilder in the country was setting himself.

On visiting Boston, the authors noted that the great Fore River Shipbuilding Corporation, which forms one of the group of large shipbuilding concerns controlled by the Bethlehem Steel Corporation, was proceeding with large extensions, two large new berths having just been completed. This concern had also just commenced operations on new ground outside Boston, where an extensive new yard was to be laid down, and a programme of destroyer building started without delay. A contract for 50 destroyers had just been taken, and delivery of these had been promised within the space of two years.

At these works, in which fully 10,000 men are employed, the authors obtained their first insight into the methods, and secured some knowledge at first hand of the machinery and appliances which make it possible for the American shipbuilders, in these times of great opportunities, to make good. Everything that can be done to simplify the work outside, and every appliance that makes work easy and reduces manual labour to the minimum, is here very much in evidence. This applies especially to the steel working department, the thorough equipment and organisation of which contributes so much to the success of every shipyard.

The mould loft in this yard (as was observed in all American shipyards) might properly be termed the thinking department for the steel workers. At the Fore River Yard, in this building, measuring 600 ft. by 100 ft., from 50 to 100 men are at work, producing in wood or paper every detail of the ships' structure, down to the smallest item. The work to be done by the steel workers is thus made so simple that the merest novice can mark a plate or bar with the greatest ease, experienced supervisors looking on and checking the work as it proceeds. The steel workers' shops, or "fabricating" shops, as they are called in America, differ in many respects from those in British shipyards. The different

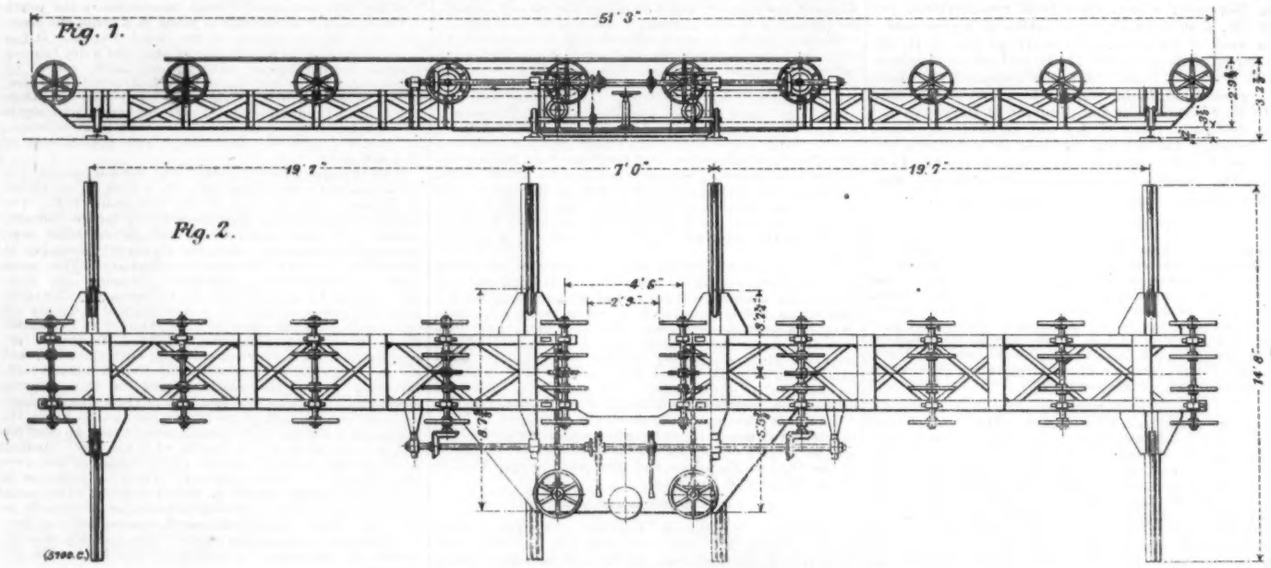


Fig. 1. The Lysholm Traversing Plate Punch.

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders on Tuesday, December 17, 1918.

shops are divided into plate and angle-working bays. Overhead engine shop cranes run from end to end, and wall cranes also run along each side of each bay. Punching and shearing machines are arranged along each side, material being moved easily from one to the other, thence to the countersinking, planning, and scarphing machines, and to the rolls when required. At the Fore River Works, the authors saw the Lysholm punch table at work for the first time, and subsequently found that this admirable mechanical device was being introduced largely into the majority of the shipyards of America. With this machine, the largest plate is punched more quickly and accurately by an unskilled man seated in front and operating a lever with each hand and a contact with his right foot, than is usually done at home by a skilled plater and seven to nine helpers. Indeed, on first seeing this machine at work, the authors were so much impressed with it and the possibilities it opened up, that they at once got into communication with the owners of the patent, from whom detailed plans were obtained, and on their return home one of these machines was without delay constructed, and is now at regular work at the shipyard at Londonderry. Space does not permit of a detailed explanation of this machine.* The diagram (Fig. 1) will give a more accurate impression of it at a glance, than would a detailed description. The introduction to British shipyards of these punch tables, which can be fitted to ordinary punching machines, will, it is confidently believed, be only a matter of time, and will help materially not only to eliminate bad or careless punching, but will also considerably reduce cost.

Material moves rapidly through the shops into the large assembling space at the head of the building berths, and is there riveted where practicable and raised into position by overhead cranes running on gantries. The overhead crane is a familiar feature in the majority of American shipyards. Not a single pole derrick with its winch and long lead of wire rope, so familiar in even first-class British shipyards to this day, was seen in any shipyard on the American continent.

The close study of methods and appliances which was subsequently made in the course of their tour, forced the conviction upon the authors that if British methods and appliances had been less traditional and more modern, the vexed problem of the dilution of labour in the steel working departments in the old country would have offered less difficulty, and would probably have been found as easy of solution, comparatively speaking, as was the case in the engineering trades when the overwhelming demands for munitions of war opened the eyes of all to the possibilities of the case.

The next yard visited was that controlled by the Vickers interest at Montreal. This yard, which is situated in a district where, for about four months in the year, the St. Lawrence River is frozen, has accounted for a remarkably good output since the outbreak of war. A unique and necessary feature in this place is the completely enclosed building berth (there are four of

*[The Lysholm traversing plate punch was illustrated and described in ENGINEERING of December 14, 1917, page 641.—ED. E.]

Fig. 3.

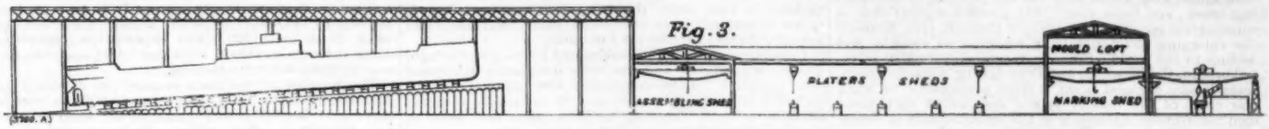
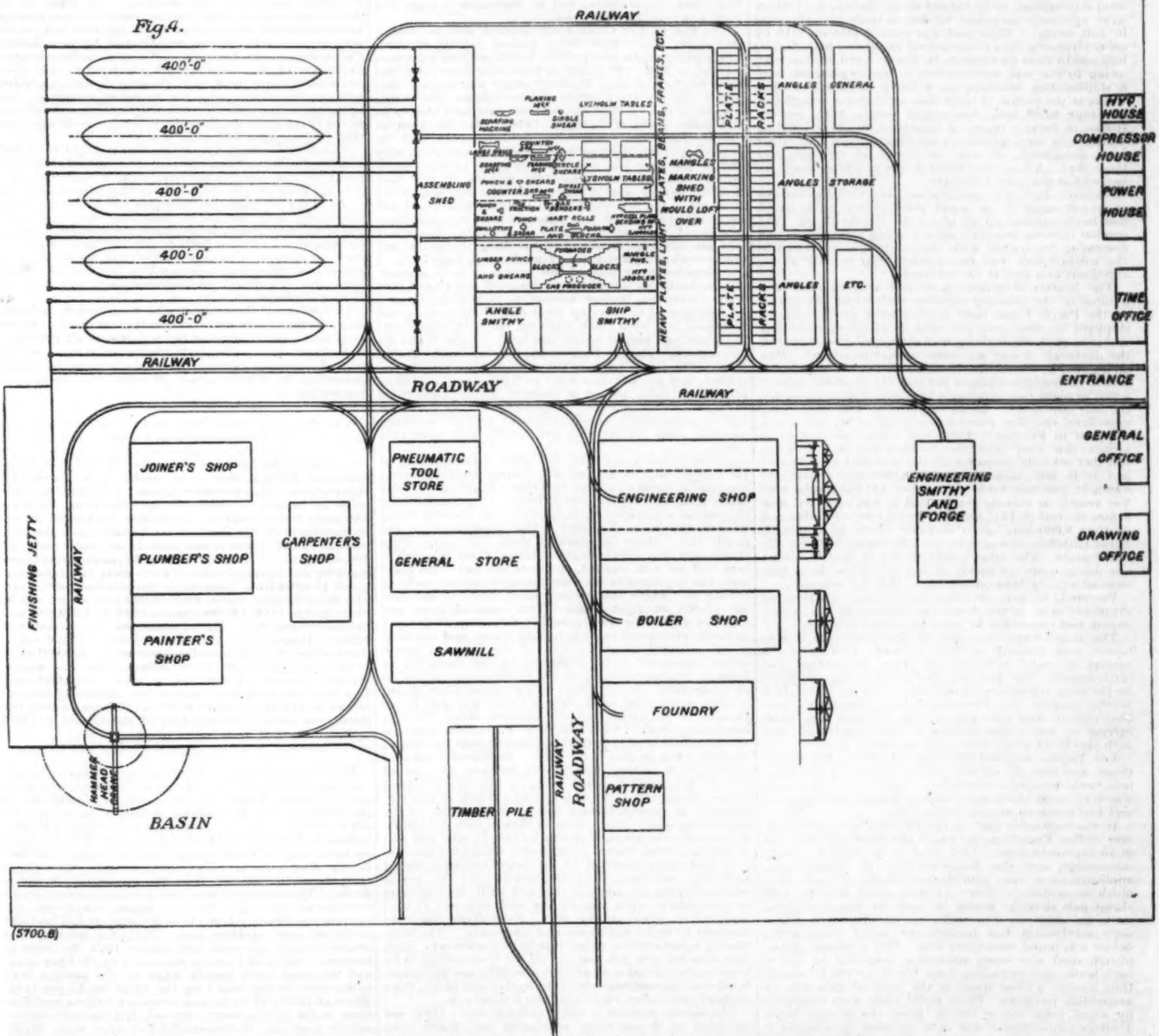


Fig. 4.



FIGS. 2 AND 3. THE SUN SHIPBUILDING YARD AT CHESTER, PENN., U.S.A.

these) heated by means of hot air during the long winter. A great feature appears to be in store for this fine shipyard, a future which it is believed will repay Messrs. Vickers for their enterprise in establishing it here.*

Ottawa was next visited, and here the authors had the pleasure of meeting at the offices of the Canadian Munitions Board, Colonel Gear and some of his principal colleagues, with whom they had the privilege of exchanging views, and from whom they gleaned a great deal of information regarding the present plans of this Ministry for enlarging the shipbuilding resources of Canada, and adding to the world's tonnage in steel and wooden ships.

Toronto, Collingwood, and Port Arthur, visited in turn, were busily engaged upon a large programme of small war craft of the trawler type; and whilst each place seen contributed materially to the valuable data in course of collection, space will not permit of entering as fully into descriptions of these places as would, under other circumstances have been preferable.

Vancouver, B.C., was reached early in November, and in this out-of-the-way and altogether unlikely place for steel shipbuilding to be carried on profitably, the authors were agreeably surprised to find a large new shipyard in full swing. This yard was started late in 1916 by an enterprising firm of structural engineers, who, finding business in their own particular line at a serious discount, owing to the war, were endeavouring to establish here a shipbuilding business on a fairly large scale. The works at the period of their visit were almost completed, and four 9,000 tons deadweight vessels were on the stocks, in various stages of construction. Five building berths only were prepared, overhead cranes had either been completed, or were in course of erection over these slips. A large new boiler shop was almost ready for use within the yard boundary.

Victoria, B.C., was next visited, and here the authors inspected some of the wood shipbuilding yards which had lately sprung up all along the Pacific Coast. The opinion formed, however, after visiting these places and discussing the matter with various people interested in the subject was that the wooden ship is only a war expedient and that it has no future.

The Seattle shipyards gave the authors their first glimpse of the amazing rapidity with which the people on the Pacific Coast have accomplished great things in shipyard development, and also in actual shipbuilding. As far as steel shipbuilding was concerned, Seattle before the outbreak of war was more or less moribund. But, undeterred by the enormous distances over which supplies had to be transported, and the scarcity of skilled labour, seven or eight new shipyards had been laid down within the last two years. As an example of what was being done here, one firm alone had started to lay out a new shipyard in February, 1916, and when this place was visited, this yard (with five berths) was in full swing, and had actually prepared all the material on the spot, and built and launched eight 8,000-tons deadweight steamers, and two 9,000 oil tankers. On the stocks were five vessels in various stages, and it was expected that before the end of 1917 another 10,000 tons oil tanker and another 8,000-tons cargo steamer would be launched. These launches it was subsequently learnt, had actually taken place. The other yards visited at Seattle, whilst not doing quite so much in the record-breaking line, were all equally bent on emulating this fine example.

Portland, Oregon, in turn, could show two thriving shipyards to her credit, both, like the yard at Vancouver, owned and controlled by steel structural engineers.

The magnificent shipyard at San Francisco it was found, was working at high pressure, turning out a variety of craft, including war ships, oil tankers, and cargo vessels. The fine new yard at Alameda, laid down by the same interests as those controlling the Union Iron Works, namely, the Bethlehem Steel Corporation, was also visited, and here also a large business was being carried on under almost ideal climatic conditions, and with the finest plant that could be collected.

Los Angeles was the last place of call on the Pacific Coast, and here the authors visited another of the many new yards brought into existence since 1916. This place was very much like those visited at Seattle and Portland, and laid down on almost similar lines.

It was noticeable that, in the Pacific Coast yards, outside of San Francisco, the plant and buildings were not of an expensive order. They were at the same time very serviceable, and the American love of labour-saving appliances, was, even in moderately equipped yards, very much in evidence. Even when in small British yards cheap pole derricks would be used for lifting material on board ships on the stocks, on the American side a very serviceable but inexpensive aerial transporting device was found over every ship. This consisted of two plough steel wire ropes stretching from end to end of each berth, and extending from 100 ft. to 200 ft. ahead, thus leaving a clear space at the head of each slip for assembling purposes. These aerial wires were supported by wood poles rising 100 ft. from the ground level. Trolleys ran overhead and were operated by winches at the head of each berth. The work done by these aerial transporters was quite good, and general satisfaction with the arrangement was expressed by the majority of superintendents.

In the San Francisco yards, the arrangements generally are on a more elaborate and costly scale, but not so elaborate nor so costly as those on the eastern seaboard.

From the moment the material enters the yard, until it arrives finished and ready for erection at the ship, it moves methodically and easily from point to point. The transporting appliances are carefully designed; the stack-yard and marking shop, platers' shops, assembling space, and building berths all have their special lifting and transporting appliances. The building berths are served by means of 5-ton jib cranes, two on each side of each berth running on steel gantries. Work proceeds night and day in three shifts of 8 hours each, and three ordinary cargo vessels and oil tankers of 8,000 to 10,000 tons deadweight are launched from each slipway every twelve months. Every shipbuilder in the United States appears to have made this his rule, namely, to launch three vessels per year from each berth, and some are actually doing it at the present time.

Crossing overland and breaking the journey at Chicago, Detroit was visited and one very interesting lake yard was inspected. Lake freighters, 600 ft. long and of 10,000 tons deadweight were seen on the stocks or at the finishing wharf. Erecting facilities were here seen at their best, very large "T" shaped cranes spanning each berth.

Returning to New York, visits were made to Newport News, Baltimore, Philadelphia, and Chester. Very large extensions were being made to the yards at Newport News and Philadelphia, and at Baltimore a large new yard was nearing completion.

The Sun yard at Chester was finished, and five vessels in various stages were being pushed rapidly forward. The making of the new yard at Baltimore had only been started in July, 1917, and in December four ships had been finished, a large finishing wharf was almost completed, the necessary offices and workshops were within a week or two of finishing, and the first keel was to be laid down early in January, 1918. The fine yard at Chester had been commenced in July, 1916, and by December, 1917, the yard was completed, and it is easily one of the best laid out and equipped in the United States. The authors formed the opinion of this yard that the designers of it had studied all that was worth studying in the best yards in the United States, and had been granted a very free hand in working into their scheme, all the best features of other yards. The result was an excellent combination, making for quick and cheap work everywhere (see Figs. 2 and 3, page 741).

A detailed description of this yard may be of interest. All the buildings have been so designed and placed that when extensions become necessary, little difficulty will be experienced in carrying these out. The power plant is housed in a large brick building, the usual transforming plant and switch boards are here, so also is the air compressing plant. Four compressors, each giving 2,500 cubic ft. of free air per minute were already installed, and preparations were well forward for another compressor being placed in position, giving 5,000 cubic ft. of free air per minute. A special store and workshop had been provided for pneumatic tools, and the necessary machine tools for carrying out repairs were here provided.

About 1,200 ft. up from the river frontage, and in close proximity to the railway siding, where all steel material is stacked, a large two-storey building has been erected, 600 ft. long and 100 ft. broad. The ground floor is used as a marking shop, a section at the end being used at present as a smithy. The upper storey is the mould loft. Over the marking shop, two engine shop cranes run the whole length. Every plate and bar is here laid out and marked, and does not leave this place until the machines in the fabricating shops are ready to receive it. These fabricating shops, three in number, are placed at right angles to the marking shop, and measure 400 ft. by 100 ft. each. One shop is devoted to heavy plates and another to light plates, and the third to all sectional material. Ten of the Lysholm punch tables mentioned at the beginning of this paper are at work in this place, and give the greatest satisfaction to all concerned. At the lower end of these three shops, a large assembling shed, 600 ft. long and 100 ft. in breadth, runs parallel to the marking shop. In this assembling shed a vast quantity of finished material can be stored ready for the ship, and a great amount of riveting work is also done here. Bulkheads, sides of casings, deck girders, deck-houses, hatches, &c., are all riveted here, and handled easily by the two overhead cranes which run from end to end. Each of the five slipways at present formed run at right angles to the assembling shed. They measure 600 ft. long by 100 ft. in breadth, and are each served by two 15 tons and two 20 tons overhead cranes. The cranes within the assembling shed carry material to the large doorways facing each slip, and from there the cranes over the berths transport with the greatest ease and with the minimum of attendance, even the largest and heaviest riveted piece to its place on the ship. Everything has been designed to make work easy and interesting. The large plating squad with its gangs of helpers is unknown. Each man does his own job, and is paid for it according to its value, or to the value at which his services are appraised. Work goes on continuously in shifts, day and night, three shifts of eight hours each being the general rule.

The labour position is not a difficult one. There are no lines of demarcation separating one trade from another, and no hard and fast rules laid down to prevent men entering a trade after reaching a certain age, or to prevent men from transferring their services from one department which may not suit them to another which may be more congenial. Wages are good, and men seem to be satisfied. Working costs are necessarily high at present, owing to the enormous pressure being exerted to produce new tonnage under difficulties, but with the excellent facilities provided, and the organisations which are being built up, there does not appear to be any reason to doubt the capacity of the American shipbuilder, and the men engaged in the industry, to turn out good work on a competitive basis when the old competitive days return.

America is undoubtedly establishing a shipbuilding industry in these days of stress which, if she so desires, may go a long way to make her a great maritime power. It is estimated that at the present moment there are close on 900 shipbuilding berths either finished or under construction all round her coasts.

The programme of the Emergency Fleet Corporation provides for the building of 2,100 steam vessels for passenger, cargo, oil carrying and refrigerating purposes, ranging from 5,000 to 12,000 deadweight each. The aggregate deadweight tonnage will be, as previously stated, 14,715,000, completed during the three years 1918, 1919, and 1920. The expenditure provided for these three years (1918, 1919 and 1920) amounts to the sum of 1,000,000,000*l.* sterling.

The number of workmen engaged in shipbuilding in American yards in July, 1917, was 45,000; a year later there were 300,000 men engaged in the shipyards alone, and 250,000 in allied trades. It is expected that by 1920 there will be close upon 1,000,000 men engaged in the shipbuilding and accessory trades.

To the question, what will America do with the large mercantile fleet she is building when the necessities of the great war have been overcome, the reply of the American is that a great carrying trade is being planned between North American ports on the east and on the west coasts and South America, Central America, Russia, China, Japan, and Australia, and doubtless the enormous expansion of the world's trade which must take place when the last and greatest of the world's wars has ended, will provide ample scope for American enterprise, and at the same time leave our own shipbuilding and carrying trades in the same strong position, if not in a stronger one, than they enjoyed before the war.

The authors would like to say that it might be as well if shipbuilders, and also the shipbuilding trade unions in Great Britain, were to pay very close attention to what is being done on the other side of the Atlantic and not to be chary in ruthlessly scrapping old practices, hoary traditions, and out-of-date methods and machinery where the advantages to be gained are obvious. British manufacturers in other fields of industry have found it to their advantage (sometimes after long hesitation that nearly cost them their best markets) to learn something from the American manufacturer, and why not the British shipbuilder?

In conclusion the authors wish to gratefully acknowledge the invariable kindness that they received wherever they went, and to express their thanks to all principals and officials at the shipyards who received them always with the greatest courtesy, gave them every facility of inspecting the shipyards, and affording them all possible hospitality.

* [A fully illustrated description of the works of Canadian Vickers Limited appeared in our issue of October 11 last (*vide* page 393 *ante*). Ed.E.]

The Shantung Iron Mine.—The Japanese Government, says *The London and China Telegraph*, has definitely decided to place the development of the Chin-ling-chên iron mine in the hands of the mining department of the Shantung Railway instead of concluding a contract for this purpose with a private concern. The Chin-ling-chên mine is located 5 miles off the Shantung Railway, 180 miles from Tsingtau. Published analyses of the ore in the time of the German occupation gave the iron content at 65 per cent., manganese 24 per cent.; with over 100,000,000 tons of ore present. Preparations had been made by the German authorities to erect two blast furnaces 11 miles from Tsingtau for the reduction of this ore. The Seito Shimpo states that 50,000 tons of ore will be excavated in 1918, 150,000 tons in 1919, and 300,000 tons annually thereafter. The expenditures are estimated as follow: Construction of branch railway, 125,000 dols.; new ore cars, 450,000 dols.; five locomotives, 325,000 dols.; houses and equipment, 75,000 dols.; wages and miscellaneous expenses, 75,000 dols.; total, 1,050,000 dols. The land for the branch railway line, according to local report, has been purchased from the Chinese owners, but permission for the construction of the line is withheld by the Chinese Government.

Big Mercury-Vapour Rectifiers.—A plant of largest size mercury-vapour rectifiers was installed two years ago by Messrs. Brown, Boveri & Co., of Mannheim, in the small town of Hirschberg, in Silesia, to replace the old rotary converters. According to J. Obach (*Elektrotechnische Zeitschrift* of October 17 and 24, 1918) the plant operates very well, although there were some troubles in the first months. The town receives three-phase currents of 10,000 volts from the provincial electricity works. These currents were transformed into continuous currents of twice 220 volts by rotary converters, the conversion efficiency being 0·85 per cent. at full load and 0·65 per cent. quarter load. Batteries were further wanted to take the peak load, and in 1913 the losses in batteries, cables and meters amounted to 19·5 per cent., and the total losses (partly borne by the average load being only 75 per cent.) by the town to 45 per cent. When an enlargement became necessary various modifications in the system were proposed, but mercury-vapour rectifiers of the Hartmann-Schäfer type were finally adopted, although there was little experience available with large-size apparatus of this kind. The three cylinders, each working with 48 kilogs. of mercury, deal with currents of 750 kilowatts. The mercury is contained in the lower portion of the cylinders, while the cooling devices for the electrodes are in the upper portion, on the top of which the arc-striking device is mounted. The anodes are of iron and suspended from a ring; a vacuum of 0·005 mm. of mercury, measured by a McLeod gauge, is maintained on the cylinders. The cooling is necessary to prevent loss of mercury; these losses amounted altogether to 1·8 kilogs. in the first half-year, and the average efficiency of the conversion is said to exceed 90 per cent. It is not quite clear what this efficiency signifies. The installation is considered very successful, however.

NOTES FROM THE NORTH.

GLASGOW, Monday.

Scotch Steel Trade.—In this, the last full working week of the year, every endeavour is being made by steelmakers, as well as by those in the associated branches of industry, to "clear the boards" of all arrears of work, so far as this lies in their power. Apart from this activity, the position remains, practically, unchanged. It is evident, however, that gradually the firm hand of control is being removed, although it is well known that some considerable time must elapse before manufacturers can possibly enjoy that freedom of action which was theirs in pre-war days. Even already, in some cases, it has been deemed advisable to drop the priority certificate, but nothing definite must be assumed from this fact. Orders are plentiful, alike from home and overseas customers, but meantime steelmakers are giving their first and best attention to the home consumer, who, of necessity, has been sadly neglected during the past four years or so. The pressure for delivery, naturally, is intense, and likely to continue, because the growing demands from export consumers cannot long be neglected, whereas at the moment only very limited shipments are being put through. Shipbuilders are in the market for large supplies of steel plates, sections and sizes, and this class of work will be much in evidence for some time to come. Steel for constructional purposes is also greatly in demand.

Malleable Iron Trade.—In the malleable iron trade there is no lack of good business, although makers are already on the hunt for orders, alike from old and new customers. The mills are actively employed, mainly, of course, on rollings for home consumption. Export is still slow of coming in, even at the revised rate of 18*l.* 10*s.* per ton, as against that of 20*l.* recently fixed. It may be that certain consumers are holding-off in the expectation of obtaining some chance commitments from Canadian or American sources, while others again whose requirements are of an urgent nature, are obliged to fix up at the ruling rate.

Pig-Iron Trade.—The output of pig-iron is fully maintained, producers getting rid of every ton with the greatest expedition, hematite, in particular, being much in demand. While export is still rather limited, the home trade is practically booming and is at the moment, the safest and best "line," according to the makers. At present prices, they are not anxious for much overseas' dealing. The development of export will come whenever transport difficulties have been satisfactorily overcome, but even as things are yet, there is little inducement for trade, and makers are quite content to wait for better opportunities.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Monday.

Iron and Steel.—Business is gradually resuming normal conditions. There is not a great amount of unemployment. Women labour has to a great extent been shed, btu there are much the same number of men and boys engaged as during the war. Overtime, Saturday afternoon and Sunday labour, however, has almost entirely disappeared, along with the abnormal earnings of operatives. Workmen on the whole are accepting the big reductions with good grace, and grumbling is rare. In the crucible steel departments there is considerable depression. There was a falling-off during the closing weeks of the war, and this has since been accentuated. At the moment the furnace capacity is considerably in advance of the demand. As a rule furnaces have set down for two weeks for the Christmas holidays. Many of the large open hearth furnaces are stopped owing to work not having come to hand to replace the shell steel contracts cancelled at the cessation of hostilities. Overseas inquiries for constructional steel have not fructified owing to the confusion consequent on the anticipated advance in prices. The withdrawal of subsidies on iron and steel is having a serious effect on the export trade, but makers state that while fuel rates remain at their present level it will be impossible to reduce selling prices. New business in machinery of every character is finding good work for steel-making plants, and the heavy iron foundries are well supplied with work. A steady business is anticipated in railway steel for both rails and rolling-stock. Rustless steel is likely to become a feature in the manufacture of agricultural implements when the inflated prices, caused by the limited supply on the market, have become normal. Early in the war this steel was commandeered for use in aeroplane parts and for other purposes where strength and durability combined with a non-rust quality, were invaluable. It has now been released from control, and already plans are in operation for its introduction into numerous parts of agricultural machinery and other appliances which are especially subject to corrosion. Inquiries amongst makers of implements such as spades, hoes, forks, rakes, and shovels, furnish very encouraging reports. Now that manufacturers have been released from the harassing conditions which were necessary during the war, orders are pouring in from all over the world. Firms dealing with Spain and the Spanish-speaking countries of South America state that they have sufficient work in prospect to run their factories for many months to come. Those who have specialised with the East have booked good orders from Colombo, Ceylon and South India. Generally, there is a quickening demand from the home and Colonial markets.

South Yorkshire Coal Trade.—The general stoppage at the pits for the Christmas holidays has been four days. During the previous week there was the usual heavy demand from works to tide over the vacation. So serious has been the shortage, however, that collieries were instructed that for two days before the holidays they must not send certain grades of fuel that could be utilised for house gas and railway purposes, into the munition or industrial works. Merchants have been complaining bitterly of the scarcity of domestic fuel, and instructions have gone out limiting the supply to any customers up to the close of the year, to 5 cwt. at one time. As, however, the holidays at the works will be considerably longer than at the pits, considerable relief is anticipated early in the New Year. The call for gas fuel is urgent, and instructions have been given to collieries to give preference to these works in the matter of deliveries. Slacks are in strong request at maximum rates. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Monday.

The Cleveland Iron Trade.—As is usual at this season of the year business is practically suspended. With the local consuming works closed, home deliveries of pig-iron are small, and as the blast-furnaces are running as usual stocks of pig-iron promise to accumulate to some extent. Shipments both coastwise and foreign are on a very limited scale. France is absorbing the great bulk of the exports. No licences are being issued for shipment to neutrals. For home consumption, No. 3 Cleveland pig, No. 4 foundry, and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for export No. 3 and the lower qualities are 145*s.* and No. 1 is 150*s.*

Hematite Iron.—Demand for East Coast hematite is also checked by the stoppage at consuming works, and the position in this branch is consequently somewhat easier, but conditions are still such that it is considered necessary to continue the system of official control of distribution. Mixed Nos. are 122*s.* 6*d.* for home use and 172*s.* 6*d.* for export.

Manufactured Iron and Steel.—Local finished iron and steel works are closed for a fortnight, the decision to take a longer holiday than usual being largely due to the coal shortage, but advantage will be taken of the suspension of operations to carry out long overdue repairs and renewals of plant. There is plenty of work available for next year, and prospects are bright. To home customers the following are among the principal market quotations:—Common iron bars, 14*l.* 10*s.*; steel ship, bridge and tank plates, 11*l.* 10*s.*; steel angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; chequer plates, 13*l.*; steel joists, 11*l.* 2*s.* 6*d.*; heavy sections of steel rails, 10*l.* 17*s.* 6*d.*; and steel billets, 10*l.* 7*s.* 6*d.* to 11*l.*; whilst export quotations include the following: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel angles, 16*l.* 2*s.* 6*d.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel joists, 16*l.* 2*s.* 6*d.*; heavy steel rails, 15*l.* 10*s.*; and steel billets, 13*l.* 10*s.* to 15*l.*

Foreign Ore.—Enlargement of business in foreign ore is looked for early in the new year, though consumers, have rather large stocks, and imports against current contracts are coming forward well.

Coke.—Pressure for delivery of coke to the blast furnaces is somewhat easier, most pig-iron producers having, it is understood, recently received supplies sufficient to see them over the holidays. Average furnace coke keeps at 33*s.* at the ovens, and quality low in phosphorus is 35*s.* 6*d.* at the ovens.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Monday.

The Local Markets.—The shortage in the supply of coal is as acute as ever; indeed, at the present moment it is even more accentuated than it has been during the past few weeks. This is accounted for by stop days occasioned by the signing of the armistice and the General Election together with the Christmas holidays. The pressure on the collieries is, therefore, unrelieved, and with outputs unsatisfactory, the position of salesmen is embarrassing, with very little prospect of, at any rate, immediate improvement. The shortage at present applies to every class of coal on the market, and stocks are simply denuded. The amount of tonnage in the dock is still very heavy, notwithstanding the diversion of shipping. Many vessels, moreover, are loaded, but have been kept from sailing owing to the boisterous weather. A new feature on the market is the shortage in the supply of pitwood; this is largely attributable to weather conditions being such as to cause a considerable falling-off in deliveries from inland sources, while overseas supplies from the Bay have also been very scarce. Here and there collieries are fairly well stocked, but in the majority of cases the available supplies are so small that fears are entertained that production of coal may be adversely affected. The authorities, however, are cognisant of the situation, and a strong effort is being made to secure an immediate improvement.

Newport.—The supply of Monmouthshire coals is insufficient to meet even the demands of the authorities, and inland requirements, while shipments are further handicapped by the comparatively reduced outputs. There are, therefore, still heavy detentions of shipping awaiting cargoes, and practically none is released for export on private account. There are plenty of inquiries, but the authorities are not in a position to release any supplies.

The Threatened Coal Strike.—As the result of another conference of miners' delegates, following the refusal of the Executive Council of the South Wales Miners' Federation to tender notices in support of a demand for the dismissal of the lower-grade officials at the Bedwas Colliery, a strike has now been averted. The decision of the previous conference, after an animated exchange of views between the leaders and the delegates, was reversed at last Thursday's conference. The reversal of the decision, however, was only carried on a "card" vote (each "card" representing 50 members), by 1,488 to 1,213. Still, the result is satisfactory as far as it goes, and praise for the continuance of peace is to be largely attributed to the strenuous fight put up by the Right Hon. W. Brace (the ex-Under-Secretary for Home Affairs) in defence of the attitude and action of the leaders.

Demobilisation of Miners.—The South Wales miners are now being released at such a rate that at least temporary unemployment seems almost inevitable. A special meeting of the Welsh Coal Board was held on Friday, with the result that a demobilisation scheme was mutually agreed upon between the employers and the workmen's representatives. Under this scheme a strict oversight is being provided for in respect of every discharged soldier or sailor, and a central exchange is set up at Cardiff for dealing with all questions arising out of the working of the scheme, the main object of which is to secure employment to the discharged men as expeditiously as possible.

Reduced Hours of Surface Workmen.—An agreement was entered into between the respective parties at the meeting of the Welsh Coal Board on Friday in connection with the curtailment of the hours of surface workmen. It was agreed that the hours should now be 49 hours per week of six working days, exclusive of meal times. It is further provided that the reduction of hours is not to affect wages, and that the fixing of the hours is not to affect those men who may at present be working less than the number of hours indicated.

A Prospective New Demand.—At a meeting of the Executive Committee of the South Wales Miners' Federation, held on Saturday at Cardiff, there was forthcoming a hint as to the prospective policy of the federation. This will include a demand for the establishment of a six-hour day. Although the matter was not fully entered into, it was understood that the view taken was that employment could not be found on the South Wales coalfield for all the miners that will be eventually demobilised unless there is brought about a curtailment of hours. It would also seem that the Miners' Federation will make a determined attempt to do away with the principle of piece work which at present governs the wages of the coal hewers, timbermen, &c. In the event of this new policy being formulated—and there seems every probability that it will be—the men's proposals will certainly meet with strong opposition on the part of the employers, and may lead to a sharp conflict later on between the two parties.

CEMENT.—The Secretary of the War Office announces that the control of distribution of cement by the War Office by means of priority certificates has been brought to an end. Manufacturers and merchants are now at liberty to execute orders without any form of certificate, provided that in all cases priority is accorded to Government orders. The export of cement will continue to be governed by the necessary export licences, as heretofore.

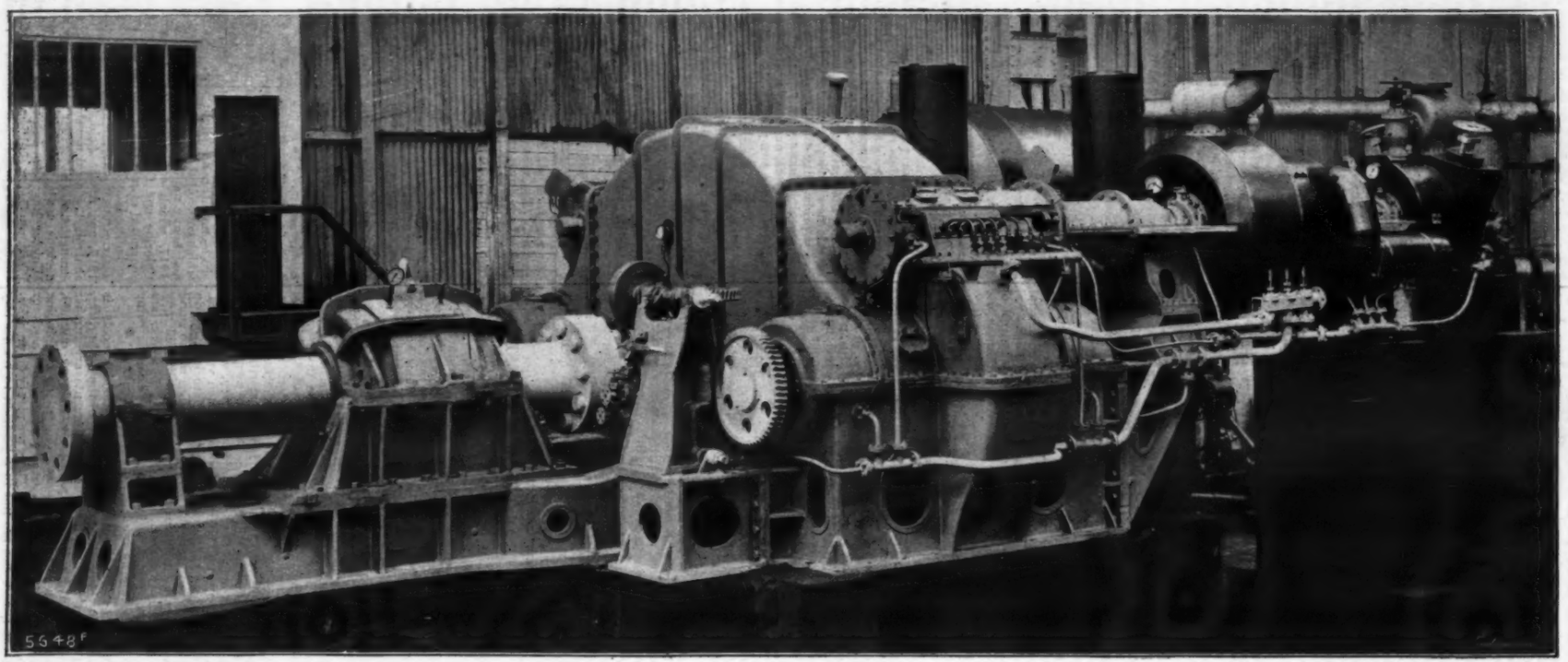
1,000-TON CONCRETE BARGE LAUNCHED AT WARRENPOINT.—The first concrete ship built in Ireland has just been most successfully launched from the yard of Messrs. J. & R. Thompson, Limited, of Belfast and Dublin. The vessel is one of several sea-going barges and steam tugs under construction on the Mouchel-Hennebique system of ferro-concrete for the Ministry of Shipping.

REMOVAL OF RESTRICTIONS ON MOTOR CARS.—The Board of Trade announce that the Motor Spirit Restriction Orders, the operation of which has been suspended until January 10, will be revoked entirely as from that date. Licences to obtain motor spirit are issued under the Finance Act, 1916, and the licence system must, therefore, remain in force. As previously announced, however, the Petrol Control Department is prepared to issue licences to new applicants and to increase the quantities allocated to existing licence holders, and will endeavour, as far as possible, to meet all reasonable requirements.

BENZOL AND OTHER CHEMICALS ORDERS. PLATINUM ORDER.—The Minister of Munitions has suspended until further notice the following Orders:—Benzol and Naphtha Order, 1917, which controlled crude benzol, crude naphtha and light oils. Naphtha Order, 1917, which controlled crude solvent naphtha, solvent naphtha and heavy naphtha. Tar (Coal) and Water Gas Order, 1917, which controlled coal tar and water gas tar. Chlorine and Chlorine Compounds Order, 1918, which controlled elementary chlorine and chlorine compounds including bleaching powder, sodium hypochlorite and all descriptions of chlorine bleach liquor. Acetic Acid Order 1917, and Acetic Acid (Extension) Order, 1917, which controlled glacial acetic acid and acetic acid of all strengths. Until further notice, grey acetate of lime and acetone cease to be specified as war material. The Minister has also suspended until further notice the Platinum Order, 1915, and the Platinum Metal Order, 1916, which prohibited purchases, sales or dealings without a permit.

DOUBLE-REDUCTION GEARED TURBINES FOR SINGLE-SCREW CARGO STEAMER.

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, WALLSEND-ON-TYNE.



THE illustration on this page represents the first set of double reduction geared turbines completed and put to use in Great Britain, the vessels having been in service since the beginning of the present year. The installation has been manufactured by the Wallsend Slipway and Engineering Co., Limited, Wallsend-on-Tyne, and this early application of double reduction gearing is consistent with the enterprise of this company since Mr. Andrew Laing, C.B.E., became responsible for the management. The first turbine installation constructed was for the famous Cunard liner *Mauretania*, the second for the Channel steamer, *Immingham*, and the third for the Battleship *Superb*; in all 48 warships and nine merchant vessels have so far been fitted with turbine machinery. The set illustrated is representative of fifteen equipments, some of which have been completed while others are in an advanced state. Of these fifteen, eleven are for driving single propellers and four are for driving twin screws, but as we hope in an early issue to give complete drawings of this interesting set, we need here only describe the salient features.

The objection taken to the application of the turbine to the tramp steamer or cargo carrier was the high rate of revolution necessary for the maximum efficiency of the turbine. This was overcome to some extent by the introduction of reduction gear, but it has now been finally dissipated by the adoption of double reduction gear, as by this means the revolutions of the propeller can be brought down to equal those of the screw operated by the reciprocating engine, and that, too, without involving any complications or additions to the machinery installation or any increase in the engine room *personnel*. The efficiency is high, and the fuel saved means a net gain in the earning capacity of the vessel. In the installation, which is very well shown in the illustration, there are three turbines working in series. The high pressure and intermediate pressure turbines are mounted in tandem, operating one of the first reduction pinions, as seen in the forefront of the view; while the low pressure turbine, operating a similar spindle, is discernable in the distance. The introduction of the treble turbine arrangement not only contributes to higher steam economy, but enables mechanical disabilities and limitations to be overcome. The second reduction wheel is placed under the first spindle, on each side of the main reduction wheel mounted on the propeller shaft.

The Brown-Curtis type of turbine has been adopted, having wheel stages throughout, the groupings of which are such as to produce equal transmission of power through each of the pinions to which reference has just been made. For reverse motion or astern going, there are two turbines working in series, incorporated respectively with the intermediate and low pressure turbines, this arrangement being conducive alike to greater efficiency and immunity from total breakdown for the astern-going machinery. To gain the highest possible economy superheated steam is employed, and this has necessitated the use of cast steel and phosphor bronze for various details which are in contact with the steam at its highest pressure and temperature.

The blading throughout is of phosphor bronze, and the rotating portions of the turbines, comprising the stage wheels and spindles are entirely made from ingot steel forgings. The thrust block, which is shown prominently in the illustration, is of the Michell type now being so extensively adopted, the design being based upon experience obtained with this type of block in other classes of work. The Wallsend Slipway and Engineering Company have now practically a standard design for each type of propelling machinery, but this standard, of course, does not in any way stereotype the design, as it is the practice of the management to utilise as quickly and fully as possible the lessons of experience in seagoing service. The standardisation also conduces to rapidity and volume of output, and thus the double reduction geared turbine for cargo ships is likely to bulk largely in the new merchant ships now being built for the British fleet. This is made obvious by the fact that during the four years 1915 to the present date, the Wallsend Slipway and Engineering Company have turned out machinery totalling 1,247,930 indicated horse-power, or an average of nearly 312,000 indicated horse-power per annum. Of the total 1,163,560 indicated horse-power were for warships. As naval work will very quickly terminate, it will be seen that in this establishment alone there is available now a great producing capacity for the completion of machinery for the mercantile marine. The total output is the more striking, when consideration is given to the low invested capital of the country, because it establishes not only efficient management but prudent finance.

4-TON DROP HAMMER PLANT AT THE LONDON AND NORTH-WESTERN RAILWAY WORKS, CREWE.

MR. C. J. BOWEN COOKE, M.INST.C.E., CHIEF MECHANICAL ENGINEER.

(*For Description, see Page* 736.)

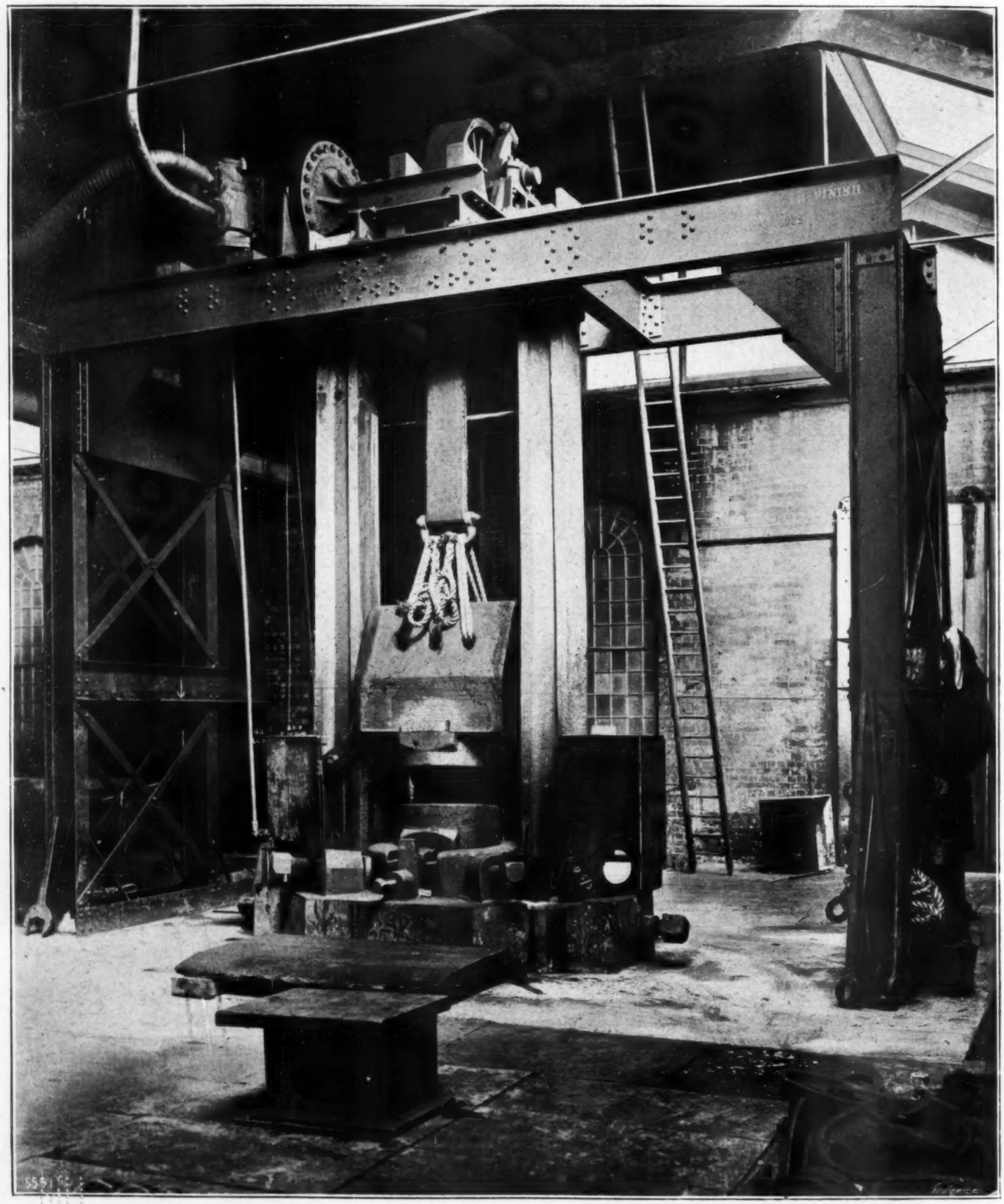


FIG. 1. THE 4-TON DROP HAMMER.

4-TON DROP HAMMER PLANT AT THE LONDON AND NORTH-WESTERN RAILWAY WORKS, CREWE.

MR. C. J. BOWEN COOKE, M.INST.C.E., CHIEF MECHANICAL ENGINEER.

(*For Description, see Page* 736.)

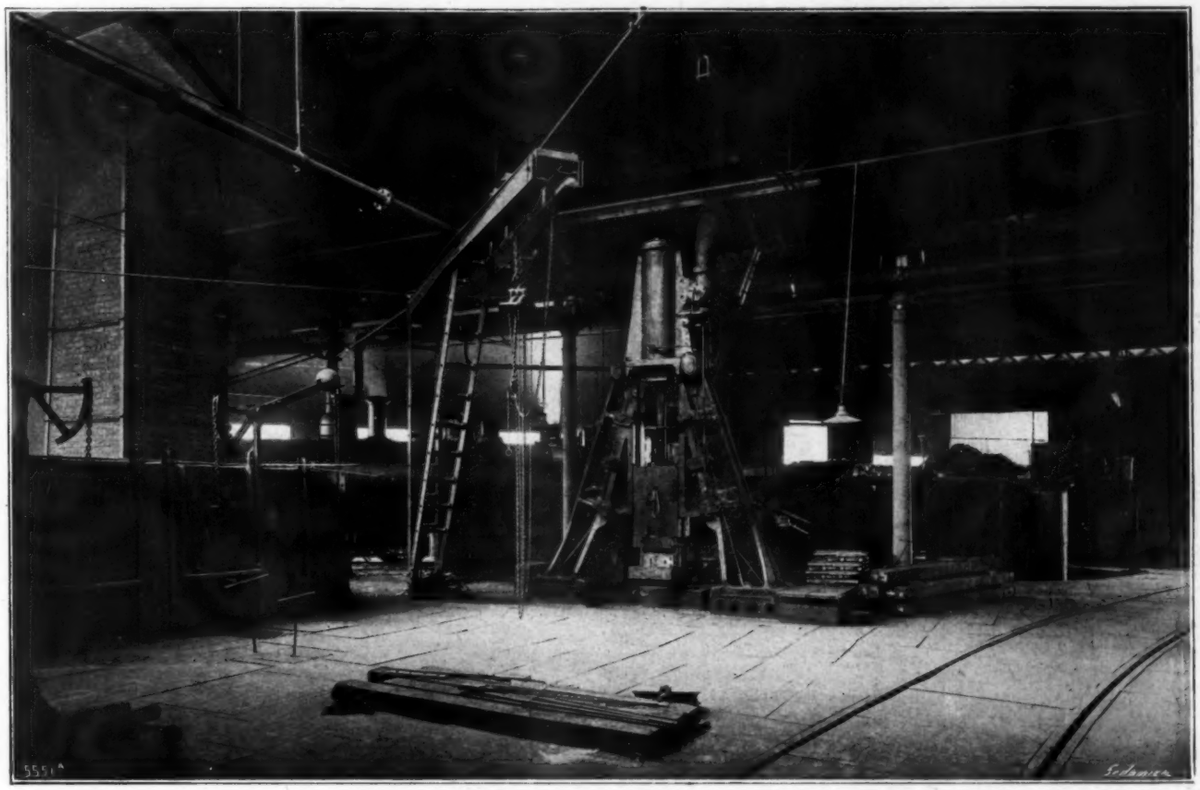


FIG. 2. 50-CWT. STEAM HAMMER FOR ROUGHING DOWN FORGINGS.

FIG 3. HEATING FURNACE.

AGENTS FOR "ENGINEERING."

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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With Two One-Page Plates of a 4-TON DROP HAMMER PLANT AT THE LONDON AND NORTH-WESTERN RAILWAY WORKS, CREWE.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

In consequence of Christmas Day falling on Wednesday this year, it has been necessary to dismiss the present issue of "ENGINEERING" for Press on Tuesday instead of Thursday, as usual.

ENGINEERING.

FRIDAY, DECEMBER 27, 1918.

ROAD TRANSPORT.

UNTIL the dawn of the present century French roads were recognised as being the best in the world. Excellently engineered and admirably well maintained they constituted a model for most countries. Moreover, owing to their centralised organisation the disappearance of traffic from the roads which arose with the development of railways was not made an excuse for neglect as it was in this country, where the control was vested wholly in the local authorities. Had it not been for the advent of the motor car the French highways would no doubt have maintained their pre-eminence, but an organisation perfectly adapted to the known and normal is often, owing to its very virtues, somewhat handicapped in dealing with novel and unexpected conditions. Our own system of providing for the control and maintenance of our highways was in some regards somewhat chaotic, but it possessed at least one very great advantage when the introduction of motor traffic made manifest the defects of all hitherto recognised systems of road construction. The multiplicity of road authorities and the absence of any central control brought about the condition that many capable men were able to initiate and carry out experiments on new methods of road making, without the necessity of appeal to some high and more or less inaccessible official who after the manner of his kind, would be far more concerned "in preventing waste by overlapping than in discovering a speedy solution of the very pressing problem in hand." Here there was overlapping in plenty, and many minds were accordingly brought face to face with similar facts, with the result that as stated by the Roumania delegate at the International Roads Congress of 1913, Britain led the world in the matter of constructing roads to meet the new conditions. As Colonel R. E. Crompton pointed out last week in his presidential address to the Junior Institution of Engineers, the problem has proved much less simple than at one time seemed likely. In the early days when the bulk of the motor traffic was light and relatively fast the great trouble was the dust problem. This was solved by tar painting, but no sooner had success been attained than the increase of heavy motor vehicles demonstrated that few of our roads were strong enough for the traffic offering. The alternative before the country was either to forbid road motor transport altogether, or to make the roads fit for the traffic. This task has proved far from easy of accomplishment, and it is very gratifying to have Colonel Crompton's statement that certain methods of construction have come with flying colours through the ordeal of the past five years. During this time there has been a marked shortage, both of the labour and materials required for road maintenance, and at the same time the roads have had, on behalf of the army, to carry an unprecedented amount of heavy motor traffic. Nevertheless, whilst in certain districts the damage done has been very serious, other highly travelled roads have borne the strain well. In particular, Colonel Crompton mentioned the main roads of Kent and Surrey, where the most improved surfaces have been laid down. He instanced in this connection the main road from London to Folkestone, where the military traffic has been abnormally heavy, yet the county surveyor is able to report that very little has had to be spent in maintaining the surface during the past four years. Moreover, in the open stretches (where not enclosed by houses) the improved road surfaces have turned out to be practically self-cleansing by the natural rainfall. With water-bound macadam very different results are observed. With these at points where the traffic has worn the crust thin, the road loses its key, the stones become loose and roll over with a consequent marked increase in the rate of wear.

It has, however, to be admitted that roads with a bituminous binding have been far from uniformly successful. In the early days of waterproofed roads the practice was to spread the metal by hand and to roll it, after which the bituminous waterproofing composition was applied through spreading nozzles and the surface re-rolled. In this way a road crust was obtained which was waterproof, and the stones embedded in the binder appeared to be sufficiently firmly held in place to resist the effects of the traffic. This type of road crust, Colonel Crompton observed, failed as time went on to maintain its level surface. Undulations or waves appeared, due to the stones being insufficiently packed. In warm weather the mixture of pitch and sand used for waterproofing actually became a lubricant allowing the stones to shift somewhat freely. A way out was, he states, discovered by Mr. Drummond, of Paisley, who devised the plan of wedging the road metal together by fragments of smaller stones or chippings. The process is thus described by Colonel Crompton: "After the coating of dry sandstone has been once lightly rolled, Mr. Drummond spread over it some of the flaky chips which he obtains from his own stone-breaking works; then, by employing men to brush the chips from two sides—i.e., in opposed directions—the chips are made to stand on end vertically, their points resting in the spaces between the larger stones. If a large roller is then carefully passed over them the wedges are driven vertically downwards, the surface becomes immovable, and the spaces left between the individual stones and the wedges are so small, that when at this stage superheated pitch is poured over the surface, it fills the small spaces sufficiently to render them waterproof, but the masses of pitch are too small to yield and change form when softened by hot weather." The procedure is said to be economical both in material and labour, and roads thus constructed have withstood for years the destructive action of heavy motor traffic driven at high speeds.

Other difficulties met with in bituminous road construction arise from the deterioration or oxidation of the binder. The remedy, Colonel Crompton said is a periodical re-tarring at a cost of 1½*d.* to 2*d.* per square yard per annum, or the tarred macadam may be covered with a carpet formed of small stone, sand or grit, and finely powdered stone mixed in with bitumen distilled from asphaltic oils. This bitumen is chemically very stable. As matters stand Colonel Crompton states that our road engineers are in a position to specify economical methods of road construction suitable for modern motor traffic moving at speeds up to 30 m.p.h. Where existing bituminous roads have become deformed, Colonel Crompton suggests that the Flammenwerfer might be adopted to soften the surface and render it sufficiently plastic to make re-levelling possible by rollers or stamps.

Not all roads, however, should be called upon to carry this type of traffic, and a cheaply-constructed road which will give good results under motor traffic at 30 m.p.h., with an axle load of 30 cwt., will fail rapidly under heavy motor vehicles moving at 8 miles an hour. Some classification of roadways with consequent traffic restrictions would, therefore, seem desirable.

As for the future of road motors, Colonel Crompton holds that axle loads should be restricted to 8 tons as a maximum. The cost of the labour required

which before the war was equivalent to a charge of from 1½*d.* to 3*d.* per net ton mile, will undoubtedly be increased, and this will make it advantageous to raise the tonnage per man employed. Colonel Crompton suggests that the solution may be found in the adoption of the Renard road train operated by current obtained from the super-power stations which have been proposed for the electrical supply of the kingdom. He holds that with trains carrying 32 tons net the labour cost would be reduced to 0·22*d.* per ton-mile, the total costs, including current, labour, standing charges and repairs being 1·51*d.* per ton, on a mileage of 12,600 miles per annum. The financial aspect sounds attractive, but it might be far from easy to ensure adequate loading of such trains. Some years ago, when one or two small firms of agricultural engine builders introduced the small steam traction engine, now so common, the makers of the heavy standard engines almost universally condemned the innovation, pointing out that the labour and fuel charges per ton-mile of the standard engines were relatively much less than with the small tractors. In a very short time, however, these critics, one and all, were themselves building the small steam tractors; which, as a matter of fact, in certain conditions, show a substantially lower cost per ton-mile than the old type of traction engine. Full loads are more easily obtained and speeds are higher, enabling a greater mileage to be made per diem, and capital charges are less. Unquestionably, if the road train system can be fully employed, the traffic charges should be lower than with other existing systems of road transport, but full loads will be essential to success.

Another suggestion in Colonel Crompton's address is that road and railway traffic should be combined. The motor lorry should, it is proposed, pick up its load at the point of origin, convey it to the nearest railway and be transferred there bodily to the railway wagon. On this it would proceed to the rail-point nearest its ultimate destination, and then proceed to the latter "under its own steam." No doubt it will, in view of the rise in wages, be imperative to reduce transhipment charges to a minimum, but the scheme thus outlined is, we think, not likely to be approved by practical railway men. Colonel Crompton notes that the suggestion will hardly be feasible with the existing limits for the structure gauge of our railways; but there are other very serious objections to the plan which will be obvious to all familiar with handling railway goods traffic, while it would also involve a great increase in the gross load carried.

PRODUCTION OF OIL FROM MINERAL SOURCES.

While awaiting the development of a petroleum industry in the United Kingdom, the Institution of Petroleum Technologists is turning its attention to other mineral sources of oils and to their utilisation. It is a very wide problem which the drilling for petroleum may assist to a certain extent. Some mineral sources of oil have long been known in the country, however; the shale oil industry is a successful pioneer British industry, and the question is how best to utilise the various sources of oil in shales, poor coal, lignite, peat, &c. That consideration at once introduces the question of low-temperature or high-temperature carbonisation. Presenting, by request, a paper on "The Production of Oil from Mineral Sources" to the Institution named, on December 17, Dr. F. Mollwo Perkin, F.I.C., first dealt with this part of the problem.

The character and quality of the products obtained by the carbonisation of bituminous minerals depends mainly upon the temperature at which the operation is conducted. The character varies also, of course, with the raw material. On the whole it may be said, however, that low heat yields olefines and paraffins, and high heat aromatic hydrocarbons. But it is extremely difficult to secure an even temperature distribution in the retort, and it is by no means easy always to obtain the same products from a given material in the same proportions. As the coal is introduced cold, the first heat effect is always low-temperature distillation. The vapours then come into contact with the hot retort walls, and there is cracking and carbon deposition, largely influenced by the shape of the retort and the rate of heating. In vertical retorts the volatile products ascend through the incoming cold coal and retain much paraffinoid matter. But there is local overheating as well as in horizontal retorts, and we do not know whether the statements made as to the retort temperatures represent more than rough guesses. At moderate temperatures of 500 deg. C., however, no carbon will be deposited on the walls, and there will be little amorphous carbon in the tar. In horizontal retorts, Dr. Perkin averaged the temperatures at 1,100 deg., in vertical retorts at 1,300 deg. or 1,400 deg., and the main products of low-temperature (and high-temperature) carbonisation he estimated as follows: Gas, 5,000 (12,000) cub. ft. per ton of coal, the latter gas being richer in hydrogen; ammonium sulphate, 10 (20) lb.; tar or crude oil, 20 (11) gallons. The low-temperature tar yield may in rich cannels rise to 60 gallons, and the tar consists mainly of paraffins, olefines, and naphthenes, from which motor spirit, fuel oil, lubricants and paraffin wax are obtained; the tar acids further give disinfectants, but they are of no use as raw materials for the dye industry. Dr. Perkin insisted upon that point, because a low-temperature carbonisation company had claimed, he said, to produce more benzol and toluol than high-temperature gas would furnish; if they did, they must either use a high-temperature process or work in two stages, he thought. The aromatic raw materials (benzol, naphthalene, anthracene, phenol, cresols) for dyes, explosives, drugs, &c., were found in the tars of high-temperature carbonisation. In the discussion Dr. A. E. Dunstan remarked as to this feature that to obtain benzol, &c., the temperature minimum was 700 deg. C.; these aromatic hydrocarbons did not come from the tar, however, but were stripped from the gas.

Dr. Perkin classed the oils obtained by the carbonisation of bituminous materials with the natural oils—of which last year over 60,000,000 tons were produced altogether—as mineral oils, though both kinds were probably organic in origin. Apart from the Scottish shale oil industry, which produced some 275,000 tons of crude oil per year before the war, the country was still entirely dependent upon imported oils as regards fuel for ships and aeroplanes, a demand which would become heavier in the future. One of the chief difficulties that had confronted this country in the production of petrol, fuel oil, lubricants, and paraffin wax from mineral sources had been the action or inaction of the Government. The publication of a paper on this new industry, read last February before the Institution of Petroleum Technologists, had been censored. A committee on low-temperature retorts and on the whole problem was appointed, however—Sir Boverton Redwood referred subsequently to the interim report issued by that committee—and Dr. Perkin could speak of much experimental work carried out on semi-commercial lines and of large schemes under consideration. Success ought surely to be possible, he pointed out, in the country, in which James Young first devised low-temperature distillation in 1847, believing the oil, that flowed from some coal workings in Derbyshire, to have been produced by low-temperature distillation of coal by terrestrial heat. When Young's patents expired in 1864, the Scottish shale oil industry expanded; but the almost simultaneous discovery of petroleum in America gave it a severe shock. Before the war the production of oil from shales in Great Britain amounted to 275,000 tons or over 70,000,000 gallons; the oil was obtained from 3,000,000 tons of shale, and yielded 600,000 gallons of motor spirit, 4,400,000 gallons of naptha, 20,000,000 gallons of burning oil, 12,000,000 gallons of gas or fuel oil, and 10,000,000 gallons of lubricating oils, in addition to 55,000 tons of ammonium sulphate and 25,000 tons of paraffin wax—products of a total value of 2,000,000*l.* per annum. The crude oil yield, more than 40 gallons per ton in Young's days, now averaged only 23 gallons. As regards the ammonium sulphate which has enabled the Scottish shales (now mined in Linlithgow and Midlothian) to withstand competition, Dr. Ormandy pointed out that though more and more sulphate would be wanted in the country for agriculture, the recovery of this product was no longer a controlling factor in the industry, owing to the general production of this ammonium salt in America, Japan and elsewhere. The shale retorts, as briefly described by Dr. Perkin, are specially designed to yield a maximum both of oil and ammonia, the former being produced in the upper cooler section of the vertical retorts, the ammonia in the hotter lower section into which superheated steam is injected. Dr. Perkin characterised the process as a low-temperature process as regards the oil, and medium-high as regards ammonia. The residue from the shale containing no free carbon was unfortunately valueless both as fuel and as mineral, and enormous dump heaps accumulated. The ordinary shale retort was not adapted, moreover, for dealing with caking bituminous materials, nor with cannels and non-caking coals, and much research had hence been carried out to devise suitable retorts for treating bituminous material, containing a large amount of fixed carbon, for the purpose of securing volatile products and a good smokeless domestic fuel.

Financial success of low-temperature practice, Dr. Perkin considered, was possible on three lines: (1) By production of oil and of smokeless fuel; (2) by production of oil and by conversion of the fuel residue into power gas; (3) by production of oil, using a portion of the residue as domestic fuel and gasifying the remainder. The first plan would answer in districts where little power was required, but where coal and cannel were at hand; the second plan would be preferable in power districts, and a certain amount of smokeless fuel should always be produced probably. Dr. Perkin gave the results of some comparative analyses which he had made of the products obtained by the Tarless Fuel Syndicate, carbonising at 500 deg. C., and by another company working with Glover-West retorts at a flue temperature of about 1,400 deg. C. (these latter figures in brackets): coke, volatile matter, 9·87 (1·31) per cent.; fixed carbon, 74·5 (86·9) per cent.; ashes, 12·59 (9·27) per cent.; nitrogen, 2 (1·5) per cent.; yield of gas per ton gasified, 128,000 (175,000) cub. ft.; British thermal units of gas, 139 (132) per cub. foot; ammonium sulphate, 101 (23) lb. Dr. Perkin felt convinced that Germany had produced large quantities of oil during the war, as before it, by low-temperature carbonisation, whilst over here Lord Curzon had admitted that, at one time, only 900,000 tons of oil had been available against the minimum of 1,500,000 tons required by the Admiralty. One reason why low-temperature carbonisation had hung fire in this country was that inventors and company promoters made exaggerated claims. The distillation of bituminous material yielded an emulsion of oil and water, containing 30 per cent. or 40 per cent. of the latter, which was exceedingly difficult to separate from the oil; all that was lumped in as oil, however.

Passing to other sources for oils, Dr. Perkin mentioned first the large beds of Kimmeridge shales in Dorset and Norfolk. The yield was good; unfortunately the oil contained from 6 per cent. to 8 per cent. of sulphur, which so far could not economically be eliminated during retorting or refining. Then there were the thick and large seams of lignite and brown coal in Devonshire, occupying in the Bovey Valley 12 square miles or 15 square miles, and having an outcrop at Bovey Tracey. Those deposits had been known since 1689. Against the utilisation of the lignite was its unpleasant odour on burning and its high ash; coal had hence replaced this lignite, even in domestic grates. Before the war, however, a company erected an electric power station of a 100 h.p., burning the lignite in a producer for the vertical engines. The lignite was delivered to the producer at 2*s.* 6*d.* a ton, its consumption averaged 3·4 lb. per brake horse-power, and the Board of Trade unit could be obtained at 0·06*d.* The retorted lignite yielded 33 gallons to 35 gallons of crude oil per ton of dried lignite, and the coke produced proved satisfactory in a suction-gas plant. The company was English, but had employed German chemists and drillers, thinking to save thereby. The lignite and brown coal also contained certain proportions of "montan wax," which was valuable for boot and other polishes, on account of its high melting point. Dr. Perkin had examined

this wax—which, as Dr. Ormandy stated, is found in pockets in the lignites of Bohemia—on behalf of the Chiswick Polish Company, and he thought the wax might be extracted before retorting. With regard to peat, the great difficulty, of course, was drying. By distilling Scottish peat (containing 14·6 per cent. of moisture and 53·5 per cent. volatile matter) with super-heated steam right down to carbon, Dr. Perkin had obtained 1·9 gallons of spirit (without scrubbing the gas), 13·8 gallons of fuel oil (flash point 184 deg. F.), phenols (in the fuel oil) 1·6 gallons, retort carbon 50 lbs., and, further, 2·5 gallons of wood spirit (methyl alcohol and acetone), 23·8 lb. of acetate of lime, and 8 lb. of ammonium sulphate.

Dr. Perkin's chief oil source is, however, coal. He would put an export tax on coal and restrict the open grate to smokeless fuel with 8 per cent. or 9 per cent. of volatile matter, sufficient to ignite easily and to give a superior heat. If the 45,000,000 tons now burnt for domestic purposes were partially carbonised, yielding at a low estimate 20 gallons of crude oil per ton, some 700,000,000 gallons or 900,000,000 gallons (2,900,000 tons or 3,750,000 tons) of crude oil would be gained per annum, in addition to 156,000 tons of ammonium sulphate. He would also distil the coal dust accumulating in the mines and the poor coal, of which one company now dumped 700 tons daily; that coal coked well and gave 50.12 per cent, of fixed carbon, 28.47 per cent. of volatile matter, and 21.41 per cent. of ashes, he had found; the ash percentage was high, of course. The 15,000,000 tons of railway coal might also better be utilised by adopting electric working. When the Government had been pressed, however, to give facilities for testing various retorts for semi-carbonisation, they had not assisted those who had experience with fuel oils, but had approached the gas works. But the Government wanted likewise benzol and toluol, which could not be produced at the same time as fuel oil, except in the form of creosote. Why then had they asked the gas works to try heavy steaming cannels whilst withholding facilities for putting up low-temperature carbonisation plant? Gas engineers, like Dr. Colman, Mr. J. West and Mr. Bond had certainly risen to the occasion, and had worked out a process for steaming in vertical retorts. They had produced a fairly good fuel oil; what did it amount to however? The Mineral Oil Production Department had undertaken to adapt several installations of retorts to this process; Nottingham had since May, 1918, produced in seven months 945,000 gallons of fuel oil, treating 150 tons of coal daily; Dundee and Bradford had, since September, each produced in 2½ months 450,000 gallons (200 tons of coal daily); the further plants at Bolton and Nelson had not been completed. The cost of conversion of the retorts had been 100,000*l.*, the average material treated cost 25*s.* per ton, and it yielded 30 gallons of oil per ton carbonised at 1*s.* per gallon, exclusive of labour and operating charges. Dr. Perkin, it will be seen, advocated low-temperature carbonisation in general without specifying any particular process.

THE RAILWAY PROBLEM.

AN essential preliminary to a full appreciation of the railway problem and of the best means of solving it is a study of the position of the various companies at the time war broke out. We feel strongly on this point, because a phrase which is being constantly reiterated is that British railways are no longer able to pay their way owing to the enormous increase in their wages bill and, therefore, there is no alternative to nationalisation. This statement has not only been made in the daily press, but even railway officials have taken the same line, while Mr. Winston Churchill has gone to the length of saying, in effect, that under State control the working of the railways at a loss may be contemplated without apprehension. We think it would be extremely unfortunate for the country and the commercial community if it were to be accepted that it is not disadvantageous for the State to trade at a loss. The application of such an unsound doctrine is only limited by the bankruptcy of the State! If British railways are to be run at a loss for the benefit of a section of the community, there is no valid argument why gas, electricity or even food should not be provided at less than cost price. The only sound basis is that every commercial concern and every nationalised commercial concern should be run on the basis of requiring the receipts and expenditure to balance. If, however, the acquisition of the railways by the State is merely an expression of a socialistic tendency, then it is high time for the commercial community to express their opinion very definitely, because, as is well-known, the advocates of railway nationalisation on socialistic principles do not stop at the railways, but desire also to nationalise mines, shipping and, indeed, practically everything else.

What we now desire to show is that so far as the railway financial position is concerned, the pre-war situation of the companies differed only in degree from what it is to-day. For years past the railways have been faced with increased expenditure, and between the years 1895 and 1912 the percentage of working expenditure to gross receipts advanced from 56 to 63, as the following figures demonstrate:—

RAILWAYS OF THE UNITED KINGDOM, 1895 TO 1913.

Year.	Length of Line Open for Traffic.	Total Number of Passengers Carried. (Exclusive of Season Ticket Holders).	Weight of Goods and Minerals Conveyed.	Total Capital Paid-up.*	Gross Receipts.	Working Expenses.	Net Receipts.	Percentage of Net Receipts to Total Paid-up Capital.	Percentage of Working Expenditure to Gross Receipts.
	Miles.	No.	Tons.	£	£	£	£		
1895	21,174	929,770,909	334,230,991	1,001,110,221	85,922,702	47,876,637	38,046,065	3·80	56
1900	21,855	1,142,276,686	424,920,513	1,176,001,890	104,801,858	64,743,520	40,058,338	3·41	62
1905	22,847	1,199,022,102	461,139,023	1,272,600,935	113,531,019	70,064,663	43,466,356	3·42	62
1906	23,063	1,210,347,132	488,790,683	1,286,883,341	117,227,931	72,781,854	44,446,077	3·45	62
1907	23,108	1,259,481,315	515,837,116	1,294,065,662	121,548,923	76,609,194	44,959,729	3·47	63
1908	23,205	1,278,115,488	491,595,056	1,310,533,212	119,894,327	76,407,801	43,486,526	3·32	64
1909	23,280	1,265,080,761	499,909,791	1,314,406,642	120,174,052	75,037,588	45,136,464	3·43	62
1910	23,387	1,306,728,583	514,428,806	1,318,515,417	123,925,565	76,569,676	47,355,889	3·59	62
1911	23,417	1,326,316,990	523,577,178	1,324,018,361	127,199,570	78,617,824	48,581,746	3·67	62
1912	23,441	1,294,337,046	520,279,128	1,334,963,518	128,553,417	81,224,343	47,329,074	3·55	63
1913	23,691	1,454,761,000	568,201,000	1,334,011,000	139,451,000	87,320,000	52,131,000	3·98	63

* Includes nominal additions to capital on conversion, consolidation or division of stocks prior to 1913.

We have purposely referred to the year 1912 for the reason that, while we have given figures for the year 1913, they are not strictly comparable with those for the previous years. Up to the end of the year 1912, the railway returns were based on statistical statements furnished to the Board of Trade on lines defined by the Regulation of Railways Act, 1871, as amended by Section 32 of the Railway and Canal Traffic Act, 1888. On January 1, 1913, a new Act—the Railway Companies (Accounts and Returns) Act, 1911—came into force, whereby each Company in the United Kingdom was required to furnish annual accounts and statistical returns in a new form. The figures, however, are sufficient to indicate our point, viz., that in the years immediately preceding the war there was a material increase in working expenditure. In the main this advance was in respect of wages. From the time the Conciliation Scheme of 1907 was accepted by the railway companies their wages bill rapidly increased, and when war broke out there was in existence a programme of demands which would have been presented to the railway companies at the end of the year 1914, which was estimated to cost not less than 16,000,000*l.* per annum. It was to meet the growth of expenditure in wages that the Railway and Canal Traffic Act of 1913 was passed. The circumstances culminating in the passing of that Act were set out in detail in ENGINEERING, of August 3, 1917.

Briefly stated, the Act was passed to redeem a pledge given by the Government at the time of the railway strike in 1911, and it provided that any increase of rate within maxima must be upheld by the Railway and Canal Commissioners on proof by the railway company that there had been a rise in the cost of working resulting from improvements made since August 19, 1911, in the conditions of employment of their staff; that the whole of the particular increase is part of an increase of rates for the purpose of meeting such increased cost; that the advance is not greater than is reasonably required for the purpose and that the proportion of the increase allocated to the particular traffic as to which complaint is made is not unreasonable. Following the concessions made to the staff in the years 1911-12, the railway companies increased certain of their goods train rates by 4 per cent. As commercial concerns this was the only course open to them; indeed, what was forcibly pointed out by *The Times* in June, 1912, is so applicable to present conditions that we feel justified in quoting from a leading article dated June 12, 1912. "There is," said *The Times*, "a likelihood of our witnessing what so often happens in these days: much sympathy with proposals to raise wages and generally to increase expenditure of employers, followed by extreme reluctance on the part of those exhibiting sympathy to bear a part of such expenditure. . . . Who is to bear the burden of the additional expenditure caused by the increased wages and similar boons to railway servants? Is it to fall upon one class, or is it to be distributed over many, including those who have helped to bring about the increase? It is clear that, whatever changes are made in the ownership or administration of railways, this question in some form will recur. Were they taken over by the State, expenditure must increase in consequence of the rise in the standard of efficiency from year to year required by the public and the demand for shorter hours and higher wages. Either the railways must be run at a loss—that is, the taxpayer must bear the extra cost—or rates for transport must be raised." Parliament endorsed the latter opinion and the Act to which we have alluded was passed to enable the railway companies to raise their rates. It would be equally sound to now charge for transport of goods and merchandise such an amount as is represented by the increased cost of the commodity, always provided that every possible economy of operation is effected. It is for the railway companies to show that they have effected, and are prepared to effect, economies, and we believe that, were they so disposed, they could make out a very good case. By using locomotives of high tractive efficiency they have very considerably increased the weight of goods and mineral trains and by introducing systems of control the train working generally has been improved, as demonstrated by the pre-war complaint of the men of what they termed "speeding up." Then also there was a pronounced tendency to reduce operating costs by pooling agreements and other working arrangements between different companies, while, however, keeping alive the competitive spirit which, in our opinion, is essential to progress. At the same time we are not unmindful of the fact that British railways did not publish ton mileage and other statistics which would have enabled them to demonstrate by comparisons with other countries the fact that operating efficiency was being increased. Moreover, there was a disposition to ignore public criticism and to leave unanswered such vague charges as those which now find expression in the statement that British railway rates are the highest in the world, that goods rolling stock is only usefully employed for 3 per cent. of its life and that—despite the law as to undue preference—preferential treatment is given to the foreigner as compared with British producers. There was also an indisposition to confer with Chambers of Commerce or to respond to the growing demand that the system of charging for traffic should be simplified. These matters required to be faced,

and we think that the railway companies would have been well-advised to do so at the time. On the other hand, as regards statistics, they were fortified by the fact that a Departmental Committee had reported upon the whole question and had not required them to compile ton mileage, while as regards general questions of railway policy, a Royal Commission was appointed in November, 1913, under the chairmanship of Lord Loreburn, to inquire into the relationship between the Railway companies of Great Britain and the State, in respect of matters other than safety of working and conditions of employment and to report what changes if any, are desirable in that relationship. Much valuable evidence had been given before the Committee at the time war broke out, but, as in so many other cases, its work had to be suspended in consequence of the war. In our opinion there is no reason whatever why its sittings should not be resumed in order that Parliament and the country may have the benefit of its report prior to coming to a decision upon so vital a subject as the nationalisation of railways.

What we have endeavoured to show is that in regard to expenditure the Railway companies were faced with an enormous increase before the war and, therefore, the fact that the increase has come upon them as upon all other sections of the commercial community does not constitute, as we are asked to believe, an unanswerable argument in favour of railway nationalisation, or the selling of the commodity which they provide at less than cost price.

PHYSICAL CHEMISTRY AND CHEMICAL INDUSTRIES.

Nearly up to the end of the past century chemical reactions were expressed in the form of equations, viz., $Ba\,Cl_2 + H_2\,SO_4 = Ba\,SO_4 + 2\,HCl$. The equation was to be read from left to right and to indicate that in order to precipitate all the barium chloride in a solution, the equivalent amount of sulphuric acid should be added. This mode of expression was correct for the "complete" reactions of the analytical chemist who wished to remove one of the elements or components from his solution. It was quite understood, however, that the equation is only an approximation, that the last traces of a substance can hardly be determined in this way, since no substance is absolutely insoluble, while most reactions are reversible with conditions and proceed in one particular direction only until a state of balance is reached. Hence it became customary to replace the sign of equality = by two arrows $\rightleftarrows$, and that change in notation was by no means unimportant. The old notation too much suggested finality, as if we could always direct a reaction in the desired sense, so as to obtain two new products. As a rule a mixture of the two original substances (reactants) and of the two decomposition products (resultants) will be obtained in proportions varying with concentration, temperature, pressure and other factors.

Investigated from the new standpoint of equilibrium reactions old-established technical processes have assumed very different aspects, an enormous amount of valuable quantitative data has accumulated, and physical chemistry shows also how new processes, considered possible but hopeless, can be rendered practicable under suitable conditions. The present generation of chemists is duly initiated into the principles of physical chemistry at the technical colleges. The older generation did not enjoy that advantage, which many other students have to miss likewise, and they will be grateful to Dr. James C. Philip, M.A., for devoting the three Cantor lectures delivered before the Royal Society of Arts, on the Mondays, December 2, 9 and 16, to "Physical Chemistry and its Bearing on Chemical and Allied Industries." Dr. Philip is Professor of Physical Chemistry at the Imperial College of Science and Technology, South Kensington. We will attempt—although the task is difficult—to give an outline of these Cantor lectures, since the subject is of interest to engineers as well as to chemists and physicists.

Let us start from two reacting substances—gases, for simplicity sake—A and B yielding the products C and D according to the formula A and B $\underset{v_2}{\overset{v_1}{\rightleftarrows}}$ C+D.

At any moment we have to deal with a mixture of the four substances. The symbols v indicate that the change from left to right proceeds at the rate v_1 and the reversed change at the rate v_2. Action between the molecules of A and B is only possible according to the kinetic theory, when A and B collide; the number of collisions, and hence the v_1 and v_2, depend, other conditions being constant, on the number of molecules present, *i.e.*, their concentrations, which we designate by a, b, c, d; hence $v_1 = k_1\,a\,b$, and $v_2 = k_2\,c\,d$, where k_1 and k_2 are constants. The observer can only determine the the difference $v_1 - v_2$, not v_1 and v_2 separately; as equilibrium is approached, this difference becomes smaller, until $v_1 = v_2$. Equilibrium does not mean stagnation and stoppage of the reaction, however; it signifies that there is as much change in the one direction as in the other, and that $k_1\,a\,b = k_2\,c\,d$, so that $k_1/k_2 = c\,d/a\,b = K$, the equilibrium constant. Here the $a\,b\,c\,d$ are the equilibrium concentrations. However the individual concentration values may vary, the law of mass action says that, at any given temperature, Y/X is a constant, where X indicates the product of the momentary concentrations on the left, and Y this product on the right side of equations.

Dr. Philip exemplified these relations in the first instance with respect to the contact process of sulphuric acid manufacture: $2SO_2 + O_2 \rightleftarrows 2SO_3$. The formula means that the combination of sulphur dioxide and oxygen to trioxide goes together with a dissociation of the trioxide. The process was the subject of a British patent as early as 1831; it requires the use of a catalyst, and troubles with the catalyst and imperfect knowledge of the principles of the reaction prevented technical success until the equilibrium was worked out in Germany a few decades ago. When we designate the equilibrium concentrations in the customary manner by the symbol C with the suffix of the substance, the quotient $C^2_{SO_2} \cdot C_{O_2}/C^2_{SO_3}$ should be a constant K at any temperature, irrespective of the initial concentrations. The C^2 in the formula indicates that two molecules of the substance enter into the reaction. The constancy of the K has been proved by experiments with various mixtures of SO_2 with oxygen and also with nitrogen at various rates of flow. At 727 deg. C., *e.g.*, $K \times 10^3$ was found to have the value 3·55, the presence of nitrogen not affecting this value. As the temperature was raised from 528 deg. to 897 deg., the K increased from 0·015 to $81·6 \times 10^3$. This K, however, refers to the reverse reaction, the decomposition of SO_3, and we see that the higher the temperature, the more trioxide will be dissociated, and that we should therefore work at relatively low temperatures. The combination of SO_2 and O is, in fact, an exothermic reaction, evolving heat, and the quantity Q of heat evolved is given by: $d\,\log K/d\,T = -Q/R\,T^2$, T being the absolute temperature and R the gas constant; the value Q is $-47{,}300 + 4T$. To arrive at the optimum gas proportions we write the equilibrium formulæ $C^2_{SO_2} / C^2_{SO_3} = C_{O_2} / K$ or $C_{SO_3} / C_{SO_2} = \sqrt{C_{O_2}} / \sqrt{K}$, which shows that the ratio of trioxide to dioxide in the mixture is proportional to the square root of the oxygen concentration and will rise, as the latter is increased.

The falling-off in the yield of trioxide at high temperatures can also be derived from Le Chatelier's principle: When any change in the external conditions (pressure and temperature) is imposed upon any equilibrium system, then the equilibrium shifts in such a direction as partially to neutralise the change in question. This principle—really inherent in the laws of thermodynamics and in the general principle of action and reaction—says, *e.g.*, that, since heat is evolved by the formation of the trioxide, the reverse process, the dissociation of the trioxide, must absorb heat, and rise of temperature hence favours the dissociation. Similarly increase of pressure favours the formation of the system occupying a smaller volume, and would hence promote the formation of the SO_3, there being two molecules on that side of the equation against three on the other; so far, however, there is little inducement to work the contact process at high pressures. Dr. Philip did not indicate how quantitative relations can be determined by the principle of Le Chatelier and Braun, which does not seem to lend itself to calculations.

For the manufacturer it is essential that equilibrium should be reached in a reasonably short time. The velocity of most chemical reactions now is doubled and even trebled by the small temperature rise of 10 deg. C.; but high temperatures, the lecturers informed us, lower the yield. A compromise has hence to be effected as to temperature, depending upon the choice of the catalyst. With the very efficient catalyst, platinum, the contact process can be worked at 400 deg. or 500 deg. C.; ferric oxide Fe_2O_3 (from roasted pyrites) has to be heated to 600 deg. to become efficient. Dr. Philip mentioned that at Mannheim a first rough catalysis with Fe_2O_3 is followed, after absorption of the SO_2 formed, by a second catalysis with platinum.

Dr. Philip took his second illustration from the synthesis of ammonia: $N_2 + 3H_2 \rightleftarrows 2N\,H_3$, a reaction long known, but only worked out by Haber about 1905. The formation of ammonia requires high pressure. Designating the partial pressures by p, the total pressure of the mixture by P, he showed that $p^2_{NH_3}/p_{N_2} \cdot p^3_{H_2} = K$ at any given temperature, and that, since p_{NH_3} is small at high temperatures by comparison with the other partial pressures, $p_{NH_3} = 0·325\,K \times P^2$, that is to say, the partial pressure of the ammonia in the equilibrium mixture is, for low ammonia concentrations, proportional to the square of the total pressure, while the volume percentage of ammonia at equilibrium is equal to $0·325\,K \times P$, and thus proportional to the total pressure. Haber demonstrated, *e.g.*, that the volume percentage of ammonia in the equilibrium mixture was 0·12 at 800 deg. C. and 1 atm. and 3·4 (30 times as great) at 30 atm. and the same temperature. This synthesis being again exothermal, very high temperatures are not desirable; at 30 atm. the value of $K \times 10^4$ went down (Haber) from 21·3 at 561 deg. C. to 1·18 at 952 deg. C., experiment and calculation being in closest agreement, whilst at 200 atm. the equilibrium percentage of ammonia was raised to 85·8. Pressures of 150 atm. and 180 atm. and temperatures between 500 deg. and 600 deg. are hardly exceeded in practice. The actual time of contact between catalyst and gas is only a few seconds or a fraction of a second. Dr. Philip mentioned that, by extrapolation from the formula, Maxted has recently shown that the ammonia yield should decrease when the temperature was raised to 2,500 deg. at 1 atm., and should increase on further raising the temperature. He stated that he had supported this deduction by experiments; technically very high temperatures have not been tried yet.

In his second lecture Dr. Philip passed to further consideration of the reaction velocity, $V = v_1 - v_2 = k_1\,a\,b - k_2\,c\,d$. Let a_0 and b_0 be the initial concentrations of A and B, and x the concentrations of both C and D after the interval t; then $V = k_1\,(a_0 - x)\,(b_0 - x) - k_2\,x^2$. When the velocity of the reverse reaction is negligible, $k_2 = 0$, and when in a particular case the change of x with t can experimentally be observed, the velocity k_1 or K can quantitatively be determined. This can be done, *e.g.*, in experiments on the saponification of ethyl acetate with caustic soda, and the velocity coefficient is found to be constant. Going back to the general case, a reaction $A + B \rightleftarrows C + D$ is called bimolecular; a reaction of the type $A \rightleftarrows B$ (conversion into a modification) or $A \rightleftarrows B + C$ (dissociation of a molecule or compound) is unimolecular; a reaction involving more than 2 molecules is one of higher order. When all the reactants are either gaseous or liquid, the change is called homogeneous; when solids enter, the change is heterogeneous.

In homogeneous reactions the catalyst—a substance which accelerates the reaction—retains its efficiency unimpaired for long periods, provided it can be kept pure. Working with pure gases the Badische Anilin-und Soda-Fabrik used the same platinised asbestos continuously for ten years, realising a 95 per cent. yield of SO_3. But when they utilised the SO_2 from roasted blende and pyrites, the yield diminished much in spite of all purification by cooling, scrubbing and filtering, mainly owing to the

arsenic fumes apparently. To facilitate the recovery of the platinum, the catalyst is, in the Schröder-Grillo process, prepared by soaking a solution of magnesium sulphate with platinum salt and then heating the mixture; the platinum of this catalyst makes up 0·1 per cent. of the mass, and 5 grammes of platinum suffice for an output of 1 ton of oleum per day with a loss of 20 milligrammes of platinum. The exceedingly small percentage of the catalyst supports the view that the final equilibrium is not dependent upon the presence of the catalyst which acts like an oil facilitating the sliding down of a weight on an inclined plane, without affecting the total energy rendered available by the falling mass.

In the case of the conversion of acetaldehyde into paraldehyde the various catalysts (several acids, SO_2, zinc sulphate, &c.) at different concentrations all give the same K, and as K is the ratio k_2/k_1, it follows that both the reversible reactions must be accelerated to the same extent. The rate of inversion of cane sugar by acids, on the other hand, varies greatly with the acid, the relative rates obtained with hydrochloric, sulphuric and acetic acids being 100 : 54 : 0·4. Most technical catalyses, moreover, are of the heterogeneous type, and there the relations are not so simple, other factors coming into operation besides mass action. Dr. Philip referred in this connection to the hot-surface combustion (Bone-Court), and to the studies of Bone and Wheeler on the reaction $2H_2 + O_2 \rightleftarrows 2H_2O$, the combustion of electrolytic gas. This combustion looks like a trimolecular reaction; in the many series of experiments made with different gas mixtures and unglazed porcelain as catalyst the values of K did not at all prove constant on that assumption, however, but did prove constant when the reaction was considered to be unimolecular. That fact, Bone suggested, shows that the rate of change essentially depends upon the occlusion of hydrogen by the porcelain; what is measured is hence not the chemical combination of hydrogen and oxygen, which is probably instantaneous, but the physical process of hydrogen occlusion.

Another class of technically important catalyses, the hydrolysis of carbohydrates by enzymes (living organisms of complex nature) deviates from the law of mass action in so far as the velocity of the reaction, instead of being constant throughout, first increases for 40 minutes, in the case of starch and malt extract, *e.g.*, and then remains practically constant; with maltose, however, this initial period is very short. In another field, that of the hardening of oils and fats by hydrogenation—a problem to which we have referred on previous occasions—the previous history of the catalyst plays an important, not yet understood part. The catalyst generally used for the purpose of making the oil combine with more hydrogen is metallic nickel, reduced from the oxide or the hydroxide, themselves obtained from various salts; the method of reduction is of great influence. In order to secure a very fine subdivision of the catalyst, nickel carbonyl, which decomposes at 200 deg. C., has been directly mixed with the oil. Still more efficient is the Lessing process which supplies the nickel carbonyl along with the current of hydrogen passing into the oil at 200 deg. C.; the nickel then acts as soon as liberated, and excellent results have been obtained with 0·1 per cent. of nickel, whilst of ordinary nickel catalysts 5 per cent. may be wanted. For these nickel catalyses carbon monoxide seems to be a "poison."

Dr. Philip also dwelt on the oxidation of ammonia by air in the presence of bright platinum at dull red heat. The reaction is $4NH_3 + 5O_2 \rightleftarrows 4NO + 6H_2O$. We referred to this process recently in our issue of November 1 (page 498). As regards the mechanism of catalysis, it has been suggested, Dr. Philip stated, that the catalyst forms intermediate compounds, *e.g.*, with the oxygen which are decomposed again by the hydrogen. That chemical view, Dr. Philip pointed out, was only tenable if this rate of the formation and decomposition of the intermediate compound were greater than that of the uncatalysed reaction, and in many cases, for instance, with catalysis by glowing porcelain, such compounds seemed to be out of the question. Yet the physical condition of the surfaces might be altered by these intermediate reactions, and surface condensation and concentration were certainly to be reckoned with. No single theory would fit all cases of catalysis, however, and chemical and physical factors had to be taken into account.

In the domain of absorption phenomena we find again that the problems can be exactly formulated for gases and liquids, but become more complicated when solids are concerned. According to Henry's law the volume V of a gas taken up by unit volume of a liquid is proportional to the pressure P under which the absorption takes place. Thus for carbon dioxide and water, when P is expressed in centimetres of mercury and V in cubic centimetres at normal temperature and pressure, V/P has the fairly constant value 0·145. That holds also for the absorption of acetylene by acetone which takes up 250 volumes of acetylene; the acetone expands when absorbing the acetylene, and for this and other reasons the steel cylinders are partly charged with some porous absorbent, as we noted in our article, published early this year, on "Cylinders for Dissolved Acetylene."*

Since the absorption increases with pressure, and water absorbs at ordinary temperature nearly 50 times more carbon dioxide CO_2 than hydrogen, the bulk of CO_2 can be removed and separated from the hydrogen in water gas by exposing the gas to water under pressure. Water dissolves at 0 deg. C., 0·0489 volume of oxygen, 0·0239 of nitrogen, 0·0215 of hydrogen and 1·713 of carbon dioxide, and at 20 deg. C. 0·031, 0·0164, 0·0182 0·0878 volumes. More oxygen is thus taken up from air than nitrogen, and more oxygen given up again subsequently on releasing the pressure. Now air contains 21 per cent. of oxygen; by one absorption this percentage is raised to 33, and by eight successive absorptions to 97; such processes for the commercial production of oxygen have been patented, but they are hardly commercial. The purification of the crude ammoniacal liquor from sulphuretted hydrogen H_2S and from CO_2 is, however, carried out on this principle by a process patented by Hills in 1868. The liquor is passed in a tower over a series of trays steam-heated from the bottom; the CO_2 and H_2S being less soluble in the liquor than the ammonia, small percentages of the former two gases can be reduced to about one-tenth of their values, 0·12 and 0·04 per cent. Dr. Philip also referred to the caisson-sickness, which is mainly due to the liberation of nitrogen from the blood on decompression; the oxygen remains bound in the blood, in labile fixation.

Since the concentration of a gas is proportional to its pressure, we may write Henry's law also $C_l / C_g = K$, designating by the C the concentration in the liquid and the gaseous phase. When a solid is present, the amount of gas taken up by the solid C_s is also found to increase regularly, but at a slower rate than the pressure; the simple relation $C_s/C_g = K$ does not hold, therefore, but in many cases the formula $C_s / C_g^{\frac{1}{n}} = k$ is applicable, *e.g.*, for charcoal and carbon dioxide where $n = 3$. It is believed that the gas absorbed by a solid is not uniformly distributed throughout the solid as it is in a liquid. There is a "dual" relation, in fact. There is first a very rapid adsorption of gas or liquid by the surface layer of the charcoal, followed by a much slower diffusion and penetration of the gas into the interior of the charcoal (absorption). The former surface effect is a question of seconds or minutes, the latter of hours and days. The regularity of the phenomena may therefore be obscured; but many experiments made at rising and falling pressures and temperatures have established the applicability of rules. The whole series of the phenomena of surface films of gases and occlusion of gases† fall into this category. It is well known that charcoal becomes a very powerful absorbent for most gases at very low temperatures. It is not understood, however, why different kinds of charcoal from various woods, differently treated, differ so strongly as to absorptive power. The masks developed during the war for the absorption of poison gases contain charcoal. Treated successfully with "doses" of 6 litres of air charged with 1 per cent. of poison gas, Dr. Philip mentioned, three charcoals, A, B, C retained successively: A, 78, 5, 0; B, 100, 20, 0; C, 100, 100, 97 per cent. of the gas; all the three charcoals were the same, but B had been heated four hours, and C six hours longer than A.

The dual character of the sorption by solids is also distinct in cases when charcoal and other absorbents are first charged with a substance (iodine, acetic acid) by being left in contact with a solution of the substance and then shaken or left in contact with a more diluted solution of the same substance. Silk, *e.g.*, takes up picric acid from solutions, and gives it up again when shaken with the solvent afterwards, the equilibrium being reversible. If the whole dyeing process relied on this sorption only, fast colours would be impossible, but chemical reactions and other factors come into play in dyeing. Vegetable and animal charcoals, Fuller's earth, clays, colloids, are largely utilised as absorbents. We do not know why certain modifications of their preparation, frequently merely shorter or longer heating, or the presence of ashes apparently, so strongly affect their efficiency, and we cannot help that the animal charcoal, which is to remove the colouring matter and other impurities from the sugar solution, also absorbs sugar. But part of this sugar can be recovered again by washing the charcoal with water, because the process is an equilibrium reaction. All these considerations are of signal importance also in soil problems. If the soil were not able to retain the salts used for fertilisation, the rain would wash out the fertiliser. Colloidal gels in the soil seem, however, to be capable of absorbing the base (ammonia, *e.g.*) leaving the sulphuric acid to combine with the lime, somewhat as the fibre combines with the basic dye, and sewage farming is based on an adsorption of organic matter by the soil. But these problems are still obscure.

* See ENGINEERING, February 8, 1918, page 155.
† See ENGINEERING, page 562 and 583 *ante*.

NOTES.

ACTION OF REDUCING GASES ON HOT SOLID COPPER.

THE small amount, about 0·05 per cent., of cuprous oxide Cu_2O, which copper generally contains, is not considered deleterious under ordinary conditions, and it is tolerated because it could hardly be eliminated without risking the introduction into the metal of other impurities. But this Cu_2O is held responsible for the remarkable weakening which copper undergoes when it is heated above 400 deg. C. in contact with reducing atmospheres, especially of hydrogen. In our issue of November 1 last, on page 495, we briefly referred to an inquiry into these effects by Mr. Norman B. Pilling, of the American Westinghouse Electric Company, of Pittsburg. Further particulars, including micrographs, of the research have meanwhile appeared in the October Bulletin of the American Institute of Mining Engineers. Heated in hydrogen for about half an hour, a strip of soft copper, which stood at least nine bending tests, broke down under the first test, when the temperature was carried up to 800 deg. C, and the strength decreased rapidly as temperatures of 400 deg. were exceeded. At temperatures of 800 deg. and more, heating for 5 minutes was quite sufficient to deprive the copper of most of its tensile strength and ductility. In atmospheres of carbon monoxide these effects were also visible, but to a much smaller extent, and Pilling finds that if the rate of diffusion of hydrogen through hot copper is 1,000, the rates for CO, steam and CO_2 are only 65, 17, 0·5. His point is that the hydrogen reduces any Cu_2O present forming metallic copper and water vapour. The reduced metal occupies a smaller space than the oxide; voids are therefore left in the metal; these voids contain steam at high temperature and pressure, and as the metal is not permeable to steam, the metallic particles are forced apart, and cracks form between adjacent pockets; hence the mechanical weakness of the copper, which the mere reduction of the oxide to metal would not explain. In rolled and wrought copper the fine specks of oxide are evenly distributed; in cast copper they accumulate on the boundaries of the grains and make this metal very brittle in reducing atmospheres. Pilling proved this further by experiments with copper containing up to 0·5 per cent. of cuprous

oxide. Strips of ordinary copper increased by 4 per cent. in thickness when heated in hydrogen to 800 deg. C., while decreasing by 4 per cent. in density; strips of copper rich in oxygen swelled visibly and were distorted and shattered. In the presence of smaller quantities of oxygen the micrographs plainly show the development of voids and cracks. It will be noticed that the effect is attributed to the inclusion of oxides and not to the occlusion of oxygen gas. In view of the recent discussion on gas occlusion it would have been interesting to have information on the analytical determination of the oxide or oxygen; but Pilling does not touch upon that point.

Electric Currents in Metals at Very Low Temperatures.

Though it has long been understood that the electric resistance of metals increases with rising temperature, as it ought to do in accordance with theory, and vanishes altogether as absolute zero temperature is approached, some of the phenomena of low-temperature research still strike one as peculiar. Lecturing recently before the Academy of Sciences upon the systematic researches of Professor Kamerlingh Onnes, of Leiden, Professor D'Arsonval drew attention to some curious observations. Onnes calculated that the resistance of mercury should still be measurable at 4·25 deg. C. absolute, but no longer at 2 deg. C. He found that the resistance vanished at 4·18 deg. already. The mercury then turned into a "super-conductor," a very thin thread of mercury being able to carry 1,000 amperes per square millimetre without becoming warm or setting up any electromotive force at its ends. This super-conductivity was not only dependent on a critical temperature, however, but also on a critical current density, below which no electro-motive force could be observed. A little below the critical temperature this critical density was very small; on further cooling it assumed high values. Lead (critical temperature about 6 deg. C.) and tin (3·8 deg. C. absolute) proved more convenient for such experiments than mercury. With a solenoid made of 1,000 turns of lead wire, 0·1 mm. thick, Onnes obtained a magnetic field of 100,000 gauss, and the study of these fields revealed another unexpected peculiarity. When the coil was suspended in a wreak magnetic field at 1·8 deg., the field had no appreciable effect on the coil; but when the field intensity exceeded 1,000 gauss the resistance of the lead became noticeable by heat evolution; the lower the temperature, the higher was this critical field density. When there is no electric resistance, there should likewise not be any damping of currents once excited in a closed circuit after cutting off the electromotive force. Onnes calculated in one case that his lead coil, when its ends were welded together, should have a micro-residual resistance of one-twenty billionth part of its resistance at room temperature (736 ohms), and that a current of 0·6 ampere should continue to flow for several days. In the experiment he suspended the coil in a field of 200 gauss at 1·8 deg. C. absolute, turned the coil with the cryostat in which it was mounted about its vertical axis, and observed a current of about 0·5 ampere. This current decreased, owing to the residual resistance, by about 1 per cent. per hour, and was observable for four days. As soon as the temperature rose (when the coil was taken out of the liquid helium), however, the current vanished. Further experiments were made with alternating currents, induced by first approaching the magnetic field, and then withdrawing it again. If the carriers of the electric current in metals be really the electrons, then the super-conductor must offer no frictional resistance to the movement of the electrons, and the electrons once started should continue to move in closed circles. That is confirmed. It should be mentioned, however, that the exceedingly difficult experiments made by Kamerlingh Onnes are not all in accord; that is to be expected, of course.

Lorries and Trailers Revocation Order.—The Minister of Munitions has revoked the Lorries and Trailers (Returns) Order, 1917, which required returns from all persons (excepting railway companies) possessing steam-driven highway lorries or trailers.

LITERATURE.

The Life and Letters of Joseph Black, M.D. By Sir William Ramsay, K.C.B., F.R.S. With an Introduction dealing with the life and work of Sir William Ramsay, by F. G. Donnan, F.R.S. London: Constable and Co., Limited. [Price 6s. 6d. net.]

The critical examination of the work and methods of the great thinkers of one age by a master, who, in later times has trodden in their footsteps, must always be instructive and suggestive. Originality in thought and endeavour is rare, and few of us know what it means to beat out an untracked path and to make the road easier for those who have to follow it. We are content to enter into other men's labours, and are thankful if we can profit by their knowledge, and discipline our minds by availing ourselves of their exertions. In the glamour of recent discoveries and the attractiveness of what is new and startling, the pioneer spade work of a bygone age is forgotten or undervalued. A gleam of genius is required to resuscitate reputations, and to enable us to see in a proper light the worth and the merit of researches, that have ceased to dazzle or have passed beyond criticism. If proximity prevents correct estimate by reason of a faulty perspective, so remoteness creates a mist that blurs the accuracy of detail. A number of splendid reputations earned in the course of more than a century, and as Professor Donnan reminds us, in the region that particularly attracted Dr. Black, has obscured the merit and dwarfed the stature of the Edinburgh Professor of Chemistry. It has needed the illuminating touch of Sir William Ramsay to make Black and his age live again.

We may be sure that Sir William recognised to the full the desert of the man he has endeavoured to make us appreciate. He knew, none better, against what drawbacks Black had to contend, how few were the facts upon which he could build, how few the bricks with which he could construct a niche in the temple of fame. Ramsay saw in Black a man of the same calibre as himself; the accident of time had given Ramsay greater opportunities, offered him more facts, the results of longer-continued research, and provided him with more efficient apparatus, but the desire for accuracy, the need for continued experiment, for trenchant, logical, deduction, and the keen determination to get all that was possible from the facts presented, was the same in both men. Black, constructing his balance for "weighing very small masses such as the globules of metals produced by essays with the blowpipe," was the prototype of the later chemist determining the density of Niton, the emanation of radium, where the quantity at his command did not exceed 0·005 cub. mm. Professor Donnan, overlooking the work of both men from a still later standpoint, knew it when he wrote "Chemical science has traversed a long road in the period between 'fixed air' and argon. But the great investigators and discoverers remain the same, and the mantle so gracefully and honourably worn by Ramsay was none other than the mantle of the great and gentle Joseph Black."

The University of Edinburgh in Black's time was neither convenient nor spacious, and its shortcomings in other respects were not relieved by architectural ornament. The buildings, with a few later additions, dated back to 1583, and were in a sad state of disrepair. The general arrangement was better adapted for a collection of almshouses than to accommodate a dignified and flourishing seat of learning. The teaching rooms of the Professors were in general mean, straightened, and inconvenient; some of the professors whose hours of teaching followed immediately on one another were obliged to occupy the same rooms. Under such depressing conditions, Hutton produced his scheme of Geology, and Adam Smith wrote the "Wealth of Nations." David Hume and Dugald Stewart were other names that gave lustre and reputation to the University, and formed the nucleus of a learned coterie, in which Black spent his uneventful life, enriching science by his work and inspiring pupils by his example.

Black, like many another, did his most original work in his early days. He established his reputation while at Glasgow, that is before he went to Edinburgh as professor, by a thesis, in which he recorded his discovery of carbon dioxide, or as he called it "fixed air." In those days, the possibility of a solid being changed into a gas, or that gas could be made to occupy a small space, was undreamt of in chemical philosophy. Black was endeavouring to find a satisfactory solvent for urinary calculus when he was led to this discovery. The description of his experiments with Ramsay's criticism and explanation of the process adopted, is of profound interest. We approach the privilege on which Lord Brougham, at a later period commented, when he recalled the pleasure he experienced on listening to his old master recount his difficulties and how they were overcome, demonstrating the steps by which he had successfully advanced from one part to another on his brilliant course. Though as Brougham said, notwithstanding he had been fortunate enough to hear many great orators "for mere intellectual gratification I should prefer to be once more allowed the privilege, which I in those days enjoyed, of being present while the first philosopher of his age was the historian of his own discoveries, and be an eye-witness of those experiments, once more performed with his own hands." We must all share Ramsay's disappointment when he sums up, "How nearly he (Black) came to the discovery that fixed air is produced from carbon!"

The second piece of notable work that Black achieved, while laying deep and broad the foundations of chemical science, was connected with the determination of the latent heat of liquids. In the case of water his experiments gave him a result that very closely coincides with the correct value. We may note in passing his careful discrimination between "quantity" and "intensity" of heat, or between heat and temperature, a commonplace now, but the distinction was by no means clearly apprehended in Black's time. With steam he was not quite so fortunate, but he was able to give some valuable information to his friend James Watt, who, by utilising in his work on condensers Black's laboratory results, "effected a revolution in the structure of steam engines, and as a consequence in the whole of our industrial and social life." In those days it would seem that industry courted the assistance of pure science.

Another connection between industry and science, in which, however, Black was only remotely concerned, is illustrated by Ramsay's careful examination of Black's original letters. In 1782, the firm of Messrs. I. Collison and Co. sent a sample of soda to Black to be tested, declaring that it was of better quality than could be imported, and enclosing a copy of their patent. Black tested the sample and reported very favourably, which he might easily do, for the soda of the competitors was undoubtedly bad. The interesting point is, however, that under the quaint phraseology in which the patent is couched, the expert was able to recognise Leblanc's process. Now Leblanc did not begin his experiments till 1784, was not sufficiently advanced with his plans to submit them to the Duke of Orleans till 1789, and did not patent the process till 1791. Sir William remarks, "this glimpse into the past shows that as usual England was to the front in the applications of chemical discovery, and that Leblanc was not the first to use the process which goes by his name." This new light makes one less disposed to sympathise with Leblanc in his treatment by the Committee of "Salut public," who, in 1794, commandeered his patent and "awarded him the munificent sum of 24*l.* to recoup him for his losses."

Black must have given and been known to have given some attention to aerostation for, in 1784, when the Mongolfier balloon was popular, he was applied to by the author of a work on the history of this subject, asking for particulars of his experiments. He was certainly popularly credited with being the first person that attempted to make a body rise in air by means of "inflammable gas," but in his reply, Black disclaimed any merit in the simple experiments or processes that he had made or attempted, and distinctly denied that he had entertained the idea of making balloons of artificial bladders, sufficiently large to lift heavy weights or to carry a man up in the air. Ramsay examines the evidence and concludes that Black must be recognised as the first to suggest the possibility of applying hydrogen to this purpose. The point is quite immaterial, but since, obvious as the result is, it

did not occur to Cavendish, it shows the quick working of Black's mind.

No picture of eighteenth century science would be acceptable that did not contain some account of the "phlogiston" theories or fallacies. Several of the protagonists in that memorable struggle figure in these pages. Black, as is known, definitely abandoned the doctrine that Priestly upheld, and threw in his lot with Lavoisier, with whom it is well known the social relations were strained In these days, there is as we think a tendency to overrate the French philosopher in comparison with English contemporaries. So far as the relations between Black and Lavoisier are concerned, we are not prepared to accept the excuses offered by the author. The evidence of want of candour, to use no harsher term, on Lavoisier's part is clear and definite. Black had suffered detraction at the hands of Lavoisier. For much information that Black had readily supplied, he received only private letters of fulsome and insincere flattery, that disgusted Black's sense of dignity and decorum. There was no public acknowledgment of assistance or priority. Sir William Ramsay thinks that Black's attitude was not warranted. "An emotional Frenchman will express feelings perfectly genuine at the moment, yet inconsistent with his other actions. It is, however, not to be wondered at, that Black, a calm deliberate Scotsman, who never acted on impulse, should have failed to understand the mentality of Lavoisier." Like Black, we remain unconvinced, such pleading may explain the letter, it fails to explain the omission in public writings and treatises, when certainly Lavoisier was not acting from impulse.

Industrial Electrometallurgy, including Electrolytic and Electrothermal Processes. By ERIC K. RIDEAL, M.A. (Cantab.), Ph.D., F.I.C. London: Baillière, Tindall and Cox. [Price 7*s.* 6*d.* net, bound.]

INDUSTRIAL electrometallurgy and electrochemistry have brought many disappointments to their advocates. It is the fault as much of the enthusiasts who made rash promises and started improvements based on inadequate research, as of the manufacturers who, having worked out remunerative processes after many years of hard struggle, were little inclined to risk the installation of new plant in the expectation of doubtful advantages. The early electrometallurgist was mostly an electrician; the furnaces did not satisfy the metallurgist and gave trouble to the electrical engineer at the power station. The development of the English electrochemical industry was further retarded by a third factor, the dearth of competent electrochemists and electro-metallurgists. Colleges and works could supply well-trained engineers, electricians and, to a lesser degree, technical chemists. The electrochemist is still difficult to find. Electrochemistry has hardly been raised to the dignified standing of a "subject" in our English higher educational system, as Dr. Rideal expresses it. The few lectures of the college course of physical chemistry devoted to electrochemistry cannot impart the theoretical grounding which should precede, or run parallel with, the technical training of the electrochemist. That want is now felt. The war has taught the easy-going manufacturer the necessity of progress based on research and scientific methods; he is willing to try electrochemical methods, but experienced electrochemists are scarce. Dr. Rideal's book will be of valuable aid in training them.

It is a good book, instructive and clear throughout, and reads well. Dr. Rideal does not waste words; he notices the most recent literature, and his treatment differs in several features from that of allied publications. The reader will always be interested and in general be satisfied, except that he will ask for more. To enable the student to find what could not be given in the 250 octavo pages of the volume, Dr. Rideal has added plenty of references to his sections and compiled two indexes. He does not write for the elementary student, but he does not unduly presume technical knowledge; constructive technical details are not given. It will be noticed that the title: "Industrial Electrometallurgy, including Electrolytic and Electrothermal Processes," does not specify Electrochemistry. All organic chemistry is excluded; inorganic oxidation and reduction processes, the electrolytic manufacture of permanganates, and of the alkalis are not included. Primary and secondary batteries, and electro-analysis are not discussed; they form subjects of their own. In spite of these restrictions the subject remains so vast that Dr. Rideal's chief anxiety must have been to decide what he might leave out. The shortcomings of his book are almost all shortcomings in this literary sense. Yet we miss general chapters on electroplating, diaphragms and furnaces. Those matters may be dealt with in other volumes of the series—the volume forms one of Dr. Samuel Rideal's series on "Industrial Chemistry"; but one expects some notes on tubular and resistance furnaces, though they are "industrial" to a slight extent only and not very "chemical." Diaphragms fare badly. There is a heading, "Diaphragms and Cataphoresis"; the text under the heading, less than half a page, concerns colloids, there are five lines on the drop of potential across a diaphragm, and the term "cataphoresis" does not occur at all. These paragraphs are on page 11, at the end of the theoretical part of the introduction which deals with ionisation, potential and electrolysis, and passes on to 15 more pages on power (hydro-electric, coal, gas, oil) and on the mineral resources of the British Commonwealth. We should be sorry to cut out these pages on power; but the theoretical section is too short, though it is supplemented in the other sections.

The sections of the volume are: Electrolysis in Aqueous Solutions; Electrolysis in Fused Electrolysis; Electrolytic Preparation of the Rarer Metals (short and not up to date); Electrothermal Processes; Carborundum and Oxisilicides of Carbon; Carbides and Borides; Electrothermal Nitrogen Fixation by Metals and Metallic Compounds; Iron and Ferro-Alloys. Electroplating processes are very properly noticed in the first section under the respective metals and not separated from the metallurgical processes of cognate nature, as is usually done. In copper refining, only the multiple system is noticed, and some recent literature on high-current density-working is overlooked; there is merely an allusion to the fact that two of the largest American works prefer the series system; the relative advantages of the two systems might have been pointed out. As regards the Hoepfner chloride process, we believe that it is no longer used in any of its many modifications, owing to difficulties with the hot corrosive chloride solutions and the diaphragms; Dr. Rideal does not mention this. With respect to the Birkeland–Eyde, Schönherr, and Pauling processes of nitrogen fixation, we have merely the names and reference to another volume of the series. There are a few misprints, hardly worth troubling about: Berkeland (instead of Birkeland), Henniche (Mennicke); French accents and German modifications are accustomed to a certain disregard; the index reference to carbides is wrong, and the ordinary aluminium carbide is Al_4C_3, not Al_4C_5 (page 172; the correct formula is given on page 193). Such insignificant oversights, however, and the slip above-mentioned—the consequence of an excision presumably—do not impair the value of the book, which bears the imprint of great care. We are not sure why ionisation must take place subsequent to solution (it might be concomitant), and Lindblad's formula for the power factor might have been presented in a more lucid form. But one chiefly regrets that a man of Dr. Rideal's capability and conscientiousness has limited, or has had to limit, himself to so short a volume.

BOOKS RECEIVED.

The Six-Hour Day and other Industrial Questions.—By Lord LEVERHULME. With an Introduction by the Rt. Hon. Viscount HALDANE OF CLOAN. Edited by STANLEY UNWIN. London: George Allen and Unwin, Limited. [Price 12*s.* 6*d.* net.]

United States Department of Labour. Bureau of Labour Statistics. Bulletin No. 234. *The Safety Movement in the Iron and Steel Industry, 1907 to 1917.* By LUCIAN W. CHANEY and HUGH S. HANNA. Washington: Government Printing Office. [Price 25 cents.]

The Triplane and the Stable Biplane. By J. C. HUNSAKER, D.Sc. (Reprinted from ENGINEERING.) London: James Selwyn and Co., Limited. [Price 3*s.* net.]

Mechanics' and Draughtsmen's Pocket Book. By W. ERSKINE DOMMETT, A.F.Ae.S. London: Sir Isaac Pitman and Sons, Limited. [Price 2*s.* 6*d.* net.]

"STUDENTS FOR DEGREE COURSES."

TO THE EDITOR OF ENGINEERING.

SIR,—We should like to add our support to the suggestions made by Mr. Wollaston in commendation of the action of the University of Bristol in making special arrangements for dealing with students who may be returning from the army. We are pleased to see that other institutions are adopting a similar far-sighted policy and trust it will become general.

Men, who have spent anything up to four years in the army and now wish to take a university course or to complete one already begun, cannot afford to waste any of the time that remains for them. Some may have already passed matriculation examinations, but to require all those who have not done so to take the examination, would mean a useless delay of months that cannot be spared, particularly as the requirements of this examination may include a number of subjects quite outside the intended degree course. Satisfactory evidence of previous good education should be accepted generally by the universities for these students.

With the same object of saving as much valuable time as possible we hope to see the suggestions adopted that entries may be made without waiting for the beginning of a fresh university year and that the normal course may be cut down by a year or more.

The practice of the University of London should also be adopted by which degrees are given on attendance at evening classes or any other method of reaching the standard required. This is particularly important for those students who may be compelled by force of circumstances to earn their livelihood while continuing their studies.

While these students who have given freely of their time and abilities in the service of the nation may claim these concessions as a right, there is another reason for making them—at any rate if the number of such students is likely to be large. Unless they are dealt with as rapidly as possible the succeeding generation of students may find the way blocked for them in our universities and other institutions.

Yours faithfully,
HANS RENOLD.

CRYSTAL PALACE ENGINEERING SOCIETY (AFFILIATED TO THE SOCIETY OF ENGINEERS).—The "Wilson Premium" for the best paper read before the Society during the past session, has been awarded to W. G. S. Grimmond for his paper on "Theory and Practice of Present-day Radio-telegraphy." Other papers read during the session were "The Elimination of Faults in Power Units, by E. A. Boyd, and "The Development of the Airship," by B. G. Simmons. The premium was handed to Mr. Grimmond by Colonel Sir Archibald D. Daunay, C.E., Mayor of Wandsworth, on the occasion of the 138th distribution of certificates at which he presided on December 19.

CHEMISTS EMPLOYED IN H.M. FACTORIES.—The Institute of Chemistry of Great Britain and Ireland, 30, Russell-square, W.C. 1, has issued the following statement: "It is anticipated that many of the chemists engaged in the factories under the Department of Explosives Supply, Ministry of Munitions, will shortly be available for employment in private works or elsewhere. In view of the impetus which has been given to many branches of chemical industry during the war, and the necessity for furthering the development and extension of chemical manufacturing industry, it is important that the public and those interested in chemical manufactures should realise how great a national asset the services of these chemists may prove. These men have had advantages which rarely fall to the lot of chemists in works, since, owing to the lack of workmen, competent to conduct complicated and often dangerous chemical operations, many of the chemists themselves have been required to carry out all the manual work involved until ordinary workmen or women were sufficiently trained. In this way they have gained an excellent first-hand practical experience in running the plants and in overcoming technical difficulties. In addition they have had quite exceptional opportunities of learning the principles on which the plants are constructed and the various operations carried on. Great pains have been taken by the Factories Branch of the Department of Explosives Supply to give the chemists full opportunities of thoroughly understanding the plant and the processes with which they were working, not only in regard to purely technical matters, but also in regard to working costs. They have thus always had before them the incentive to reduce the working costs as much as possible, by the economy of raw materials, the recovery of waste products and the skilful employment of plant and labour. In other words, they have been taken into the confidence of the management of the factory, have had these aims clearly presented to them, and have been shown the best means to attain the said aims. Again, many of them have carried out on the large scale valuable investigations relating to the difficulties that have arisen in the course of manufacture, and on the recovery of waste products. They have all been taught to consider the plant operations as in the form of a balance-sheet and to account as far as possible for the yields and losses involved. There is no doubt that many such chemists can be usefully and profitably employed in the scientific management of factories and that they will prove extremely valuable to our chemical industry. The crying need in this country is for careful, thorough, scientific control of its industries and these chemists afford the chemical manufacturers the opportunity of getting reliable aid in that essential work."

THE PROPULSION OF CARGO SHIPS WITH PARALLEL MIDDLE BODY.

*Variations of Shaft Horse-Power, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single-Screw Cargo Ship.**

By Naval Constructor WILLIAM MCENTEE, U.S.N., Member.

PREVIOUS experiments made at the United States Experimental Model Basin indicate† that for slow ships of full lines, such as are used for the ordinary single-screw cargo ship, it is desirable to use a certain amount of parallel middle body. In those experiments the different models used had varying lengths of parallel middle body distributed equally forward and abaft the midship section. The present investigation had for its object the determination of the best fore and aft position for the parallel part of the ship, and the investigation of the effect of this variation on the shaft horse-power, propulsive coefficient, and wake and thrust deduction factors.

Four 20-ft. models were made corresponding to ships of 400 ft. length between perpendiculars and of 57·3 ft. beam, 26 ft. draught, and 13,137 tons displacement when fully loaded. A longitudinal or prismatic coefficient of 0·788 was chosen as representing about the present practice in cargo carriers of this type. A constant length of the parallel middle body was taken equal to 33 per cent. of the ship's length. This percentage was found in the investigations referred to above to give about the minimum residuary resistance for the speeds attained in practice for ships of this type.

In Fig. 1, annexed, are shown the lines of model 2,023 which were used as the parent form. In Fig. 2, are shown the curves of sectional area for the four models and the parent form. Model 2,132 was made very full at the entrance, with a fine run. Model 2,135 was made relatively very fine at the entrance and full in the run. Models 2,133 and 2,134 were intermediate between the two extreme models. The model with the very full bow and that with the very full stern were purposely made of an extreme type beyond anything that might be expected to be used, in order to give a wide scope to the investigation and to insure that the limiting condition as regards power should be obtained at either extreme.

In the four models the middle section of the parallel middle body—that is to say, the section which divided the parallel middle body into two equal portions—was placed at varying distances from the forward perpendicular, amounting to 31·3 per cent., 38·5 per cent., 53·4 per cent. and 60·5 per cent. of the length of the ship, respectively.

The models were carefully made and all were fitted with the same cast stern frame, which included the stern bearing for the propeller shaft. The stern frame had the rudder cast with it. The whole frame and rudder was fitted to each of the four models before the self-propulsion experiments were undertaken, and, together with the propeller shaft, propeller and dynamometer were transferred from one model to the other as the experiments with each model were completed.

The dynamometer consisted of a small direct-current motor, the armature shaft of which was directly connected with the propeller shaft by means of a flexible coupling. The armature shaft was free to float fore and aft and aft in its bearings about $\frac{1}{16}$ in. in an axial direction. The armature shaft was connected to a calibrated spring by means of a thrust bearing, so that the axial displacement of the armature shaft gave a measurement of the propeller thrusts. Similarly, the frame of the motor was mounted so as to rotate in independent bearings. The torque developed by the motor acted against a calibrated spring so that the deflection of the spring indicated the torque of the motor. In addition to this there were suitable means provided for measuring the revolutions of the shaft.

The order of procedure in making the tests was as follows: The shaft and dynamometer were carefully lined up and the whole run for a sufficient time to warm up the bearings and reduce the bearing friction as much as possible. Owing to the fact that the dynamometer was placed very close to the stern, but a short length of propeller shafting was necessary, and this was supported by two self-aligning bearings, one at the stern bearing and the other at the forward end of the stern tube. With the propeller shaft in place and everything working freely the model was towed in the Model Basin beneath the towing carriage at several different speeds, and the propeller shaft, without propeller, run at the range of revolutions to be covered in the course of the experiments. The propeller was then fitted to the shaft and cards for torque and thrust and revolutions per minute were taken with the model self-propelled at different speeds. In these tests the model was guided by two plates about 10 in. in width placed at either end of the model, so as to steer it in a straight course. The guide plates floated between the guiding points attached to the carriage, but the towing carriage did not exercise any force on the model in a fore and aft direction. Starting at low speeds corresponding to about 5 knots for the ship, the towing carriage was adjusted to run at a uniform speed. The rheostat controlling the speed of the propeller dynamometer was then adjusted so that the thrust of the propeller would just keep the model running as fast as the towing carriage, without striking the stops, which were placed at an interval of 6 in. Thus, starting with the model in the mid position, it was free to gain or lose a distance of 3 in. as compared with the towing carriage before striking either stop. When the propeller was running at the proper speed to keep the model up with the towing carriage the record of thrust, torque and revolutions per minute was taken. If, in the course of the run, the model struck either stop on the carriage the run was discarded and another run made. Having obtained the desired data at the lowest speed, the carriage speed was increased for subsequent runs and similar data taken at higher speeds. The range covered corresponded to speeds of 5 knots to 12½ knots for the ship. About 40 different runs were made with each model, giving a corresponding number of points for plotting the torque, thrust and revolutions per minute curves.

The armature of the propeller dynamometer was especially designed to reduce to a minimum the amount of magnetic thrust. This thrust increased with the torque and amounted to 0·17 lb. when the armature was displaced $\frac{1}{16}$ in. and the torque delivered to the shaft was 16 lb.-in. Neglecting this at higher powers would have caused an error in thrust measurements of 1·4 per cent., but would not have caused any error in the power measurements. However, this magnetic thrust was separately calibrated, and corrections for it were made in working up the results of the experiments.

It is interesting to note that experiments of this kind with a very heavy model, in this case a displacement of 3,774 lb., afford a very sensitive means of checking the uniformity of speed of the towing carriage. If the towing carriage itself were not very carefully adjusted, so as to eliminate slight variations in power required to drive it, owing to variations in the level of the tracks or uneven friction of the driving wheels or guide wheels, the resulting small accelerations and retardations of the carriage were made very apparent. As the model, driven by its own propeller, when supplied with a constant voltage, ran at very uniform speeds, it was possible to see the towing carriage gaining or losing distance of a few inches in 5 seconds or 10 seconds, as slight inequalities of speed due to small variations in the resistance of the driving mechanism developed. In order to conduct self-propulsion experiments successfully with the method followed, it was necessary to have the towing carriage running in excellent condition.

Immediately after completion of the self-propulsion tests on the model the propeller was removed and the runs to obtain the shaft friction and the thrust without propeller were repeated. The model was next connected with the resistance dynamometer on the towing carriage and the usual model resistance data taken. This insured that the conditions of test both for self-propulsion and for the resistance of the model would be uniform as regards conditions of the model, temperature of water, &c. Experiments on the four models were run on succeeding days, and the springs of the propeller dynamometer were calibrated both before and after the tests.

In Fig. 3, page 753, is shown one of the dynamometer cards taken for a model running at a speed corresponding to about 10½ knots for the ship. It will be noted that the deflection of the torque spring for this condition

Fig. 1.

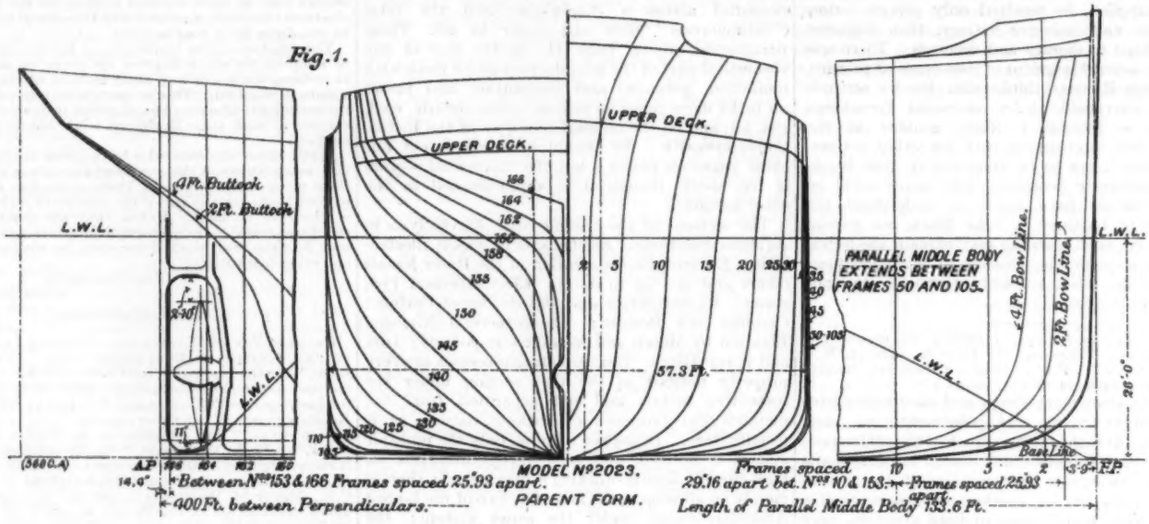
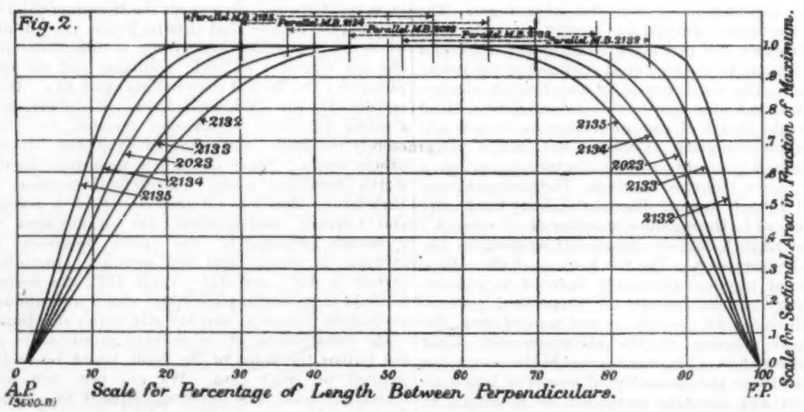


Fig. 2.



* Paper read before the Society of Naval Architects and Marine Engineers at Philadelphia, November, 1918.

† "Speed and Power of Ships," by D. W. Taylor.

was 2·47 in., for the thrust spring 2.24 in., and the interval over which the revolutions were measured was 1·78 in. With a little practice it was possible to read both the thrust and the torque deflections within 1/100 of an inch. The revolutions could be read to an accuracy of less than one-half of 1 per cent. Considering that the data taken are plotted and the whole averaged by means of faired curves, it is estimated that the results obtained as regards the three elements measured are correct within 1 per cent.

In Fig. 4, annexed, are shown the actual observations of the torque and thrust pen deflections, and the revolutions per minute of the propeller shaft plotted on speed of the model, the latter being measured by the speed of the towing carriage in the same manner as in the ordinary resistance tests.

The following are the dimensions of the propeller used in the experiments and also the dimensions expanded to the ship scale :—

	Model. In.	Ship. Ft. In.
Diameter	10·125	16 7
Pitch	9·0	14 9
Pitch ratio	0·889	
Mean width ratio	0·20	
Number of blades	3	
Ratio of projected to disc area	0.266	
Blade thickness fraction ...	0·04	

The propeller had three blades of Taylor's standard form.

The propeller characteristics were obtained by separate tests of the propeller model run in free water, that is in a separate apparatus where the propeller shaft projected well ahead, so that the propeller ran in water undisturbed by the action of the testing apparatus. The same motor dynamometer was used for the tests as was used for the self-propulsion tests, the only difference being that the propeller shaft was coupled to the forward end of the armature shaft instead of the after end.

The characteristics of the propeller are given in Fig. 5. The thrust constant C_T, and the torque constant C_Q, are plotted on nominal slip following the method used by Schaffran.* These constants, which are in non-dimensional form, lend themselves well to the analysis of self propulsion experiments and to the extension of the results to the full-size ship.

* "Systematische Propellerversuche," K. Schaffran, Schiffbau, September 22, 1915.

The results of the investigation are given in Figs. 6, 7 and 8, below. An examination of the effective horse-power curves and the shaft horse-power curves for the different models shows, as would be expected, a wide variation in power required. By plotting cross curves of power at a speed of 11 knots it will be found that, for both the effective horse-power and the shaft horse-power, the best results are obtained when the middle section of the parallel middle body is placed about 43 per cent. of the ship's length from the forward perpendicular. But 2,000 shaft horse-power is required for the ship represented by model 2,133 at a speed of 11 knots. This is considerably below that obtained with the ordinary 400-ft. cargo ship of this displacement and it may possibly be questioned to whether it is not lower than could be expected to be obtained on a real ship.

It must be remembered, however, that the lines are of good form and the friction of the shaft has been eliminated so that the powers given do not include shaft friction. As to the reliability of the method followed it may be stated that in similar experiments made on a model of the twin-screw collier Jupiter, for which are available accurate trial data, the results of the model tests, when

Fig.3. DYNAMOMETER CARD SHOWING PROPELLER THRUST, TORQUE, AND R.P.M.

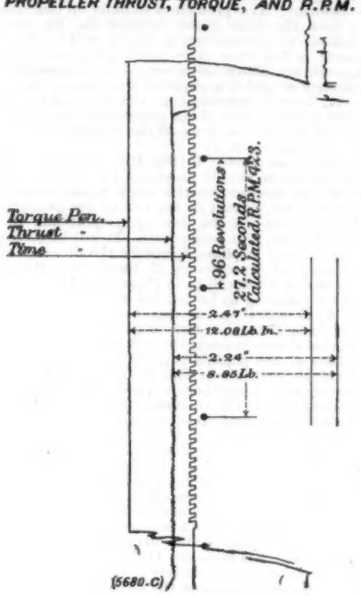


Fig.4. CURVES OF DYNAMOMETER THRUST & TORQUE PEN DEFLECTIONS AND PROPELLER R.P.M. MODEL Nº 2133.

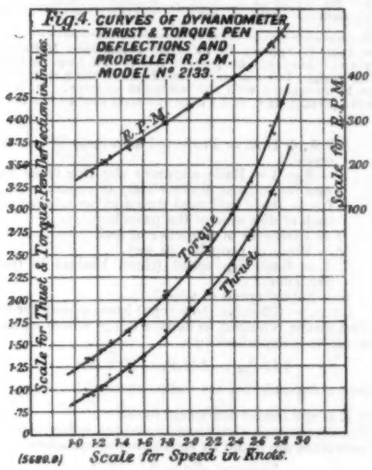
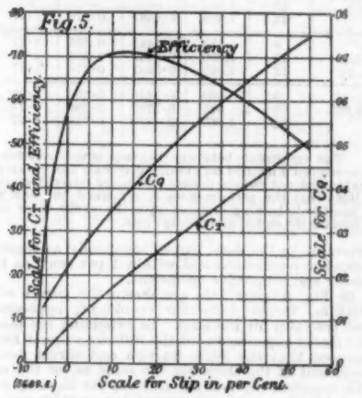


Fig.5.



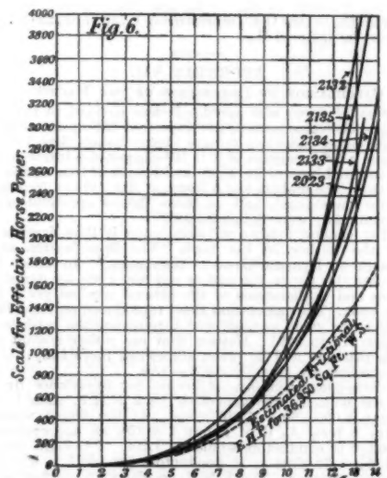
Curves of Propeller Characteristics.
Propeller No. 824.

Pitch ratio	.889
Ratio projected area to disc area	.266
Mean width ratio	.200
Blade thickness fraction	.040

$$C_Q = \frac{Q}{n^2 p^3 d^2} \qquad C_T = \frac{T}{n^2 p^2 d^2}$$

d = diameter in feet.
p = pitch in feet.
n = revolutions per second.
T = thrust in pounds.
Q = torque in pound-feet.

Fig.6.

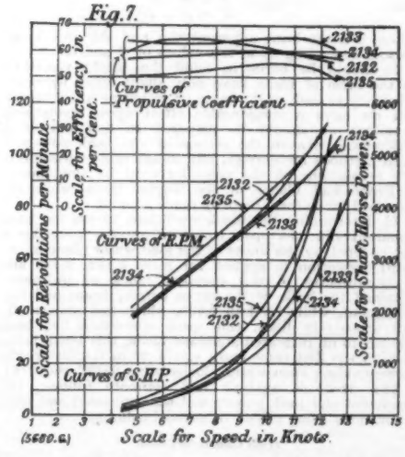


Curves of Effective Horse Power for 400-Ft. Cargo Ship.

With variable location of parallel middle body.
Beam = 57·3 ft., draft = 26 ft., displacement = 13,137 tons.
Length of parallel middle body = 133·6 ft. or 33·4 per cent. of length.

Model No.	Centre of Parallel Middle Body from F.P. in p.c. of Length.	Length of Entrance in Beam.	Length of Run in Beam.	Appendages.	Trim.
2132	31·30 p.c.	1.02	3.81	Stern frame and rudder	E.K.
2133	38·46 p.c.	1·52	3.13	Ditto	E.K.
2023	46·84 p.c.	2.10	2·54	Ditto	E.K.
2134	53.33 p.c.	2.56	2.09	Ditto	E.K.
2135	60·50 p.c.	3.06	1.59	Ditto	E.K.

Fig.7.

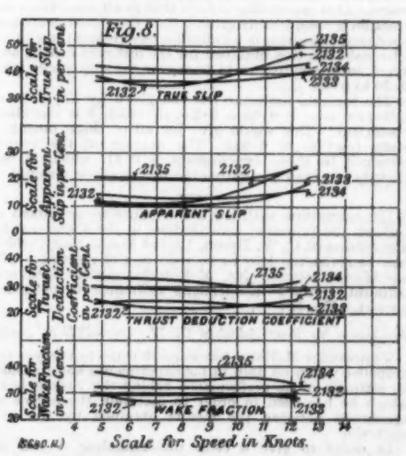


Curves of Shaft Horse Power, R.P.M., and Propulsive Coefficient for 400-Ft. Cargo Ship.

With variable location of parallel middle body.
Breadth = 57·3 ft., draft = 26 ft., displacement = 13,137 tons.
Length of parallel middle body = 133·6 ft. or 33·4 per cent. of total length.

Model No.	Centre of Parallel Middle Body from F.P. in p.c. of Length.	Length of Entrance in Beams.	Length of Run in Beams.	Appendages.	Trim.
2132	31·30 p.c.	1·02	3·63	Stern frame and Rudder.	E.K.
2133	38·46 p.c.	1·52	3·13	Ditto	E.K.
2134	53·33 p.c.	2·56	2·09	Ditto	E.K.
2135	60·50 p.c.	3.06	1·51	Ditto	E.K.

Fig.8.



Curves of Wake Fraction, Thrust Deduction Coefficient, True Slip and Apparent Slip for 400-Ft. Cargo Ship.

Variable location of parallel middle body.
Beam = 57·3 ft., draft = 26 ft., displacement = 13,137 tons.
Length of parallel middle body = 133·6 ft. or 33·4 per cent. of length.

Model No.	Centre of Parallel Middle Body from F.P. in p.c. of Length.	Length of Entrance in Beam.	Length of Run in Beam.	Appendages.	Trim
2132	31·30 p.c.	1·02	3.63	Stern frame and rudder.	E.K.
2133	38.46 p.c.	1.52	3·13	Ditto	E.K.
2134	53·33 p.c.	2.56	2·09	Ditto	E.K.
2135	60·50 p.c.	3.06	1.61	Ditto	E.K.

ESTIMATE OF PERFORMANCE.

Shaft Horse-power.

Hull.	v.	e.h.p.	$\frac{\text{e.h.p.}}{\text{E.H.P.}}$	Z.	K.	Est. Power.	Tank Power.	Log Av	Log A_s	s.	Est. Revs.	Tank Revs.
2,132	8	480	0·1415	0·89	1·27	735	750	3·48	2·78	0·09	60·4	62·0
	10	1,100	0·3243	0·51	1·27	1,762	1,800	3·48	3·01	0·1274	78·7	80·5
	12	2,580	0·7607	0·12	1·27	4,325	4,500	3·48	3·23	0·1885	101·6	109·0
2,135	8	610	0·1799	0·74	1·41	1,153	1,225	3·51	2·78	0·1379	63·75	69·0
	10	1,240	0·3656	0·455	1·41	2,220	2,250	3·51	3·01	0·1564	81·44	86·0
	12	2,500	0·7371	0·138	1·41	4,607	4,550	3·51	3·23	0·1955	102·5	109·0
2,133	8	450	0·1327	0·91	1·27	702	725	3·48	2·78	0·086	60·8	61·5
	10	925	0·2727	0·588	1·27	1,472	1,480	3·48	3·01	0·1065	76·9	77·5
	11	—	—	—	—	2,080	2,000	—	—	—	86·0	87·0
	12	1,825	0·5381	0·276	1·27	3,020	2,850	3·48	3·23	0·1316	94·9	98·5
2,134	8	490	0·1445	0·855	1·27	796	850	3·48	2·78	0·098	60·9	63·0
	10	1,000	0·2949	0·553	1·27	1,596	1,700	3·48	3·01	0·1154	77·66	79·5
	12	1,825	0·5381	0·276	1·27	3,020	3,150	3·48	3·23	0·1316	94·9	97·5
2,023	8	480	0·1415	0·89	1·27	735		3·48	2·78	0·09	60·4	
	10	925	0·2727	0·588	1·27	1,472	No	3·48	3·01	0·1065	76·9	No
	12	1,660	0·4895	0·326	1·27	2,679	data	3·48	3·23	0·1167	93·3	data

The agreement between the two power columns is so close that it appears to me that Commander McEntee has developed a method for obtaining quickly and cheaply all such data as it has taken me years to collect and from the data so obtained, not only to deduce absolutely correct factors for propeller design, but also so to classify hulls along such definite lines that the performances of combined hull and propeller can be forecasted with the minimum of error. He is most heartily to be congratulated upon the results of his labours up to the present time, and I hope and trust that he has not yet reached the end of his investigations.

extended to the ship, agreed identically as regards the propeller revolutions and within 1 per cent. as regards power and propulsive coefficient.

In Fig. 8, page 753, are shown the curves of wake fraction, thrust deduction coefficient, apparent slip, and true slip for the ship. In extending the results of the model experiments to the full-size ships it has been assumed that the wake fraction and thrust deduction coefficient of the ships are the same as for the models. The apparent slip and the true slip for the ship are less than for the model, because of less relative resistance, owing to the fact that the frictional resistance increases less rapidly than if it followed the law of comparison.

In order to avoid confusion in terms, the following definitions of thrust deduction coefficient t, and wake fraction w, are given :—

$$t = \frac{T - R}{T}; \quad w = \frac{V - V'}{V};$$

in which T is the thrust of the propeller, R the resistance of the ship, V the speed of the ship, V' the speed of advance of the propeller in the water in which it works.

As was to be expected, the wake fraction and thrust deduction coefficient both increase with fullness of the stern. It is interesting to note that in all cases the wake fraction is considerably greater than the thrust deduction coefficient, resulting in a hull efficiency greater than unity. The wake fraction obtained for the different models at a speed corresponding to 11 knots for the ship varies from 0·29 to 0·35.

The formula for wake fraction given by Taylor is as follows : $w = -0{\cdot}05 + 0{\cdot}5\,b$, in which b is the block coefficient. This would give for all of these models a wake fraction of 0·336. The average of the results obtained in these experiments is 0·31, which is but slightly less than that estimated by the above formula.

[In connection with the above paper we are asked to publish the following contribution to the discussion by Rear Admiral C. W. Dyson, United States Navy, which was received too late to be read at the meeting. The agreement between Mr. McEntee's model tests and Admiral Dyson's independent estimates is of much interest.—ED. E.]

Discussion by Rear Admiral C. W. Dyson, U.S. Navy.

Commander McEntee has requested me to analyse the propeller which he used in his experiments and to make an estimate of its performance behind the various hulls which he has used in order to ascertain the degree of agreement between the results obtained by the two methods.

In order to give a clear understanding it will be necessary for me to give a brief description of the method used by me and which has been obtained by many years' study of the performances of actual propellers driving actual ships over carefully measured courses.

The form of propeller blade selected from which to derive the design or performance factors is that of which the projected area is an oval with the greatest circular width at 0·7 radius of the propeller from the centre.

From these performances a series of basic curves of design have been obtained from which the performance of the propeller under these basic conditions can be obtained and the performance of the propeller under any other conditions of performance derived from this basic performance by the application of suitable factors entailed by the changed conditions.

The basic conditions are denoted as follows :—

I.H.P. = Basic indicated horse-power.
S.H.P. = I.H.P. × 0·92 = Basic shaft horse-power.
P.C. = Basic propulsive coefficient with maximum hull efficiency. (Taken for total projected area ratio.)
E.H.P. = I.H.P. × P.C. = Basic effective (tow-rope) horse-power.
P.A. ÷ D.A. = Projected area ratio (outside 0·2 diameter) of three-bladed basic propeller.
¼ P.A. ÷ D.A. = Projected area ratio of four-bladed screw.
⅓ P.A. ÷ D.A. = Projected area ratio of two-bladed screw.
1 − S = 1 − Basic apparent slip (for three blades) and for fullness of after body of vessel.
I.T.D = Basic indicated thrust in pounds per square inch of disc area of the propeller.
D = Diameter of propeller in feet.
P = Pitch of propeller in feet.
T.S. = Basic tip speed (three blades) in feet, of propeller.
v = Actual speed of vessel.
e.h.p. = Effective (tow-rope) horse-power for v.

The power required to deliver e.h.p. where no cavitation exists is expressed by :

$$\text{I.H.P.}_d = \text{I.H.P.} \times \text{K} \div 10^z$$

where z depends for its value upon the value $\frac{\text{e.h.p.}}{\text{E.H.P.}}$ and K is the thrust deduction factor.

The revolutions corresponding to the actual conditions of resistance are found by the following equations :

$$s = \text{Apparent slip} = S\,\frac{\text{I.H.P.}_d \times A_V}{\text{I.H.P.} \times A_r}$$

and

$$R_d = \frac{v}{P} \times \frac{101.33}{(1 - s)},$$

where S is the basic apparent slip and A_V and A_r are factors depending upon the values of V and v.

It should be borne in mind that slight variations in the form of blade have only slight effect upon the efficiency so long as the same projected area is retained, but do have a considerable effect upon revolutions, therefore we should be prepared to find but small differences between the estimated and tank powers if both methods are correct, but considerable variation in the revolutions as the propeller used by Commander McEntee had blades of the Taylor form, while the standard blade form used by me is an oval.

In determining the block coefficient to use for basic apparent slip, the open water (where the propeller is not covered by the limits of the load water plane of the ship) correction is applied for hulls 2,132, 2,133 and 2,134, directly to the standard block as ordinarily obtained for hulls of the given length, beam and displacement, while for hull 2,135, which had abnormally full after-body lines, this same correction has been applied to an increased standard block, this block being 0·80 in the first three cases and 0·85 in the latter, the corresponding open water blocks being 0·532 and 0·61.

The work of analysis and estimate follows, the estimated and tank powers and the estimated and tank revolutions being placed in parallel columns.

Hull Characteristics.

L.B.P. = 400 ft.
B = 57·3 ft.
H = 26 ft.
Displ. = 13137.
Nom. B.C. = 0·7716.
B ÷ L.B.P. = 0·1433.
Stand. B.C. for K = 0·80.
Est. Stand. B.C. for K (Hull 2,135) = 0·85.
D < . 7 H .·.
Stand. S.B.C. for V = 0·532.
Stand. S.B.C. for V (Hull 2,135) = 0·61.
K = 1·27, for 2,135 = 1·41.

Basic Condition of Propeller.

P.A. ÷ D.A. (three blades) ...	0·266
D	16·583 ft.
P	14·75 ft.
T.S.	5,900
P × R	1,671.
1 − S (for S.B.C. 0·532)	0·89
(for S.B.C. 0·61)	0·90
V	14·67
	14·84
I.T.D	3·1
I.H.P.	4,880
P.C.	0·695
E.H.P.	3,392.
S.H.P.	4,490

THE SUPPLY OF SINGLE-PHASE POWER FROM THREE-PHASE SYSTEMS.*

By Professor MILES WALKER, D.Sc.

(*Concluded from page 727.*)

APPENDIX VI.

METHOD OF CHOOSING THE COMPONENT VOLTAGES FROM THE THREE PHASES IN ORDER TO BUILD UP E′ SIN $(\omega t - \beta)$, SO AS TO GET BALANCED CURRENT IN THE CASE OF A CONDENSER BALANCER.

In this case $\beta = \frac{1}{4}\phi - \frac{1}{4}\pi = -22{\cdot}5$ deg.; therefore $-\beta = +22{\cdot}5$ deg.; so that in laying out O E′ in Fig. 40 we set off the angle at 22·5 deg. from $O E_{ac}$ anti-clockwise. The problem is to build up this voltage, O E′, from the three-phase voltages E_a, E_b, and E_c. The scheme of connections is shown in Fig. 39. The condenser is fed from three secondaries connected in series, each secondary being wound on a separate core the primary of which is supplied from one of the three phases A, B and C respectively. It is assumed that there are 1,000 turns on each of the primaries; the problem is to find the number of turns on the secondaries so as to get the desired result.

The condenser current I′ (Fig. 40) is 90 deg. ahead of E′, and is taken as 100 amperes, 100 amperes being taken as the current on the single-phase furnace I_s. The value of the current in any one of the primaries of the transformers will be directly proportional to the number of turns of its secondary. It will be seen that the only current in phase B will be the current fed to the primary of transformer B (neglecting the magnetising current); it will be in phase with I′.

As we are aiming at having the resultant currents in phases A, B and C at 120 deg. to one another, these currents must form the sides of an equilateral triangle such as that drawn in double lines in Fig. 40. The phase of the base of this triangle is given by the phase of I′; and it will be further seen that the resultant A must be obtained by adding together the vector O I_S and another vector parallel to O I′; similarly, the resultant C must be obtained by adding together the vector O I_S and another vector parallel to I′ O. Thus the height of the equilateral triangle is determined by setting off a line $I_S I_A$ parallel to O I′ and finding the point where it intersects the line O I_A, which is necessarily at 60 deg. to O I′. The equilateral triangle is then completed by drawing the resultant C, which is necessarily equal to O I_C obtained by drawing a vector $-I$ I_C parallel to I′ O. If we now scale off the currents I_S I_A, O I_S, and $-I_S$ I_C, we find that these are 114·2 amperes, 44·7 amperes and 70 amperes respectively; therefore the number of turns in the secondaries of the transformers should be 1,142, 442 and 700 respectively. If we now set off three voltage vectors 1,142 volts, 70 volts and 442 volts respectively, parallel to E_a, $-E_c$ and E_b respectively, we obtain the vector O E′, representing 1,732 volts, 22·5 deg. ahead in phase of E_{ac}.

APPENDIX VII.

CALCULATION OF DIMENSIONS OF THE MACHINE.

Size of frame and speed.—It was decided to use an eight-pole frame so as to get a speed of 750 r.p.m. Since single-phase machines require bigger frames than three-phase, a $D^2 l$ constant of 6×10^6 suggested a frame with an internal bore of 91·5 cm. and length of iron of about 42 cm. The makers had a frame of size 140 cm. (outside stator punchings), and as these figures appeared convenient they were decided upon.

The general method of calculation is that described by the author in his book "The Specification and Design of Dynamo-Electric Machinery." In order to shorten this paper, the author will rely upon the descriptions and explanations of the general method given in the book. The calculation sheet reproduced on page 724 *ante* is the same as that used throughout the book (see pages 317 to 320). Matters that are rather special to this machine will be given somewhat more fully. All dimensions are given in centimetres.

Three-phase winding.—Allowing for impedance drop in the winding, the generated back E.M.F. should be about 6,000 − 60 = 5,940 volts. As the frame would carry a total A_2 B of about 1×10^6, an approximate number of conductors would be 1,200. For eight poles 1,152 (= 72 slots × 16 conductors per slot) is a convenient number. The E.M.F. coefficient $K_e = 0{\cdot}4$ (see page 23 of book). Revolutions per second = 12·5. We thus arrive at the voltage formula—

$$5{,}940 = 0{\cdot}4 \times 12{\cdot}5 \times 1{,}152 \times 1{\cdot}03.$$

Size of three-phase conductors.—Allowing an efficiency of 90 per cent., we have 444 kw. input at unity power factor. This gives us 43 amp. per phase, or, allowing a little margin for power-factor adjustment, say 47 amp. per phase.

The size of conductor chosen was 0·26 × 0·5 (0·127 sq. cm. in area, allowing for rounded corners). This gives 370 amp. per sq. cen. at 47 amp. The 16 conductors are arranged in two rows of eight, with substantial insulation between them.

In addition to the room taken up by 16 conductors per slot, room is left for three compensating conductors, the function of which is described on page 725 *ante*. These conductors were made 0·13 × 1, as they had not to be bent edgewise. The size of slot required was 1·7 cm. wide × 3·7 cm. deep. Particulars of the lengths and resistance are given in the calculation sheet.

Single-phase winding.—The single-phase winding is placed in 48 slots at the back of the 48 slots occupied by

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* Paper read before the Institution of Electrical Engineers on December 5.

phases A and C. No single-phase slots are punched behind the slots occupied by phase B. The shape of the punchings will be seen in Fig. 21, page 723. Since a current of 2,750 amperes would require a very large conductor, and since the single-phase voltage to be generated is very low, it is obviously the best plan to put eight paths in parallel, each of which can contribute 2,750 ÷ 8 amp. This gives us 340 amp. per conductor, and at 50 cycles we should still be troubled with eddy currents if we did not split up the conductor for this current. The actual conductor chosen consists of 3 square wires in parallel. Each wire is 0·6 cm. wide (0·35 sq. cm. in area). These individual wires are crossed over in the course of connecting up, so that each wire embraces exactly the same leakage flux, and no eddy currents flow between the three in parallel. The eddy currents in the individual wires lying in the slots, calculated by Field's curves, give a mean loss 22 per cent. higher than the I^2R loss for direct current.

The number of turns required in the single-phase winding to give 234 volts at no load can be calculated as in an ordinary transformer, so long as all wires are symmetrically placed with respect to the wires in the three-phase slots of phases A and C, and have the same winding factor. In 48 slots we have $48 \times 16 = 768$ conductors. $768 \times 234 \div 6{,}000 = 30$ conductors in 6 slots (15 turns per pole) or 5 conductors per single-phase slot. *Had it been necessary to get 247 volts at no load, some of the three-phase conductors would have been cut out to increase the working flux by 5 per cent. Before the winding was completed, however, the makers of the furnace decided that they would not require more than 220 volts at no load, the relations between the various voltages on load being as indicated in Fig. 22. It was therefore necessary to cut out one of the 15 turns per pole of the single-phase winding; and the question arose whether it should be a turn embracing 4 teeth or a turn embracing 8 teeth. To determine this, it is only necessary to calculate the winding factors* for the various single-phase coils and the winding factor for the three-phase winding in the 6 slots occupied by phases A and C.

There being 9 slots per pole, the slot pitch is (electrically) 20 deg. None of the coils of the single-phase winding is of really full pitch. The largest coil, embracing 8 teeth, is short of full pitch by 20 deg.; the second, by 60 deg.; and the smallest coil, by 100 deg. Taking the winding factor of a really full-pitch coil to be unity, we have :—

Coil.	Cosine of Half-angle of Phase-difference of Coil Sides	= Winding Factor.
Longest	cos 10 deg.	0·9848
Middle	cos 30 deg.	0·866
Smallest	cos 50 deg.	0·6428
		3)2·4936
	Mean	0·831

The mean winding factor can also be found by the formula given† by Smith and Boulding for coils lying in slots, namely :—

$$\frac{\sin \frac{1}{2} m\gamma}{m \sin \frac{1}{2}\gamma} = \frac{\sin 6 \times \frac{1}{2}(20 \text{ deg.})}{6 \sin \frac{1}{2}(20 \text{ deg.})} = \frac{\sin 60 \text{ deg.}}{6 \sin 10 \text{ deg.}} = 0.831$$

Now this winding factor, 0·31, applies to the three-phase winding. Therefore, when we have 5,940 volts (virtual) generated in the 768 conductors between the terminals A and C, the volts per conductors generated are really :—

$$\frac{5{,}940}{768} \times \frac{1}{0{\cdot}831} = 9{\cdot}3 \text{ volts (virtual).}$$

We can arrive at the voltage generated by the 10 conductors making up each coil, as follows :—

Large coil ...	9·3 × 0·9848 × 10 = 91·7	volts
Middle ...	9·3 × 0·866 × 10 = 80·5	,,
Smallest ...	9·3 × 0·6428 × 10 = 59·8	,,
	232	volts for 15 turns.

If now we have only 4 turns (instead of 5) in the smallest coil, we get the figures as follows :—

Large coil ...	9·17 × 10 = 91·7	volts
Middle ...	9·05 × 10 = 80·5	,,
Smallest ...	5·98 × 8 = 47·8	,,
	220	volts nearly, for 14 turns.

Fig. 39.

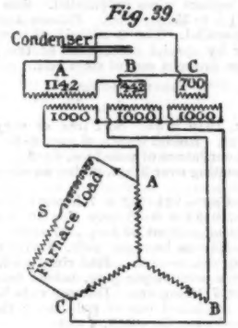

Fig. 40.

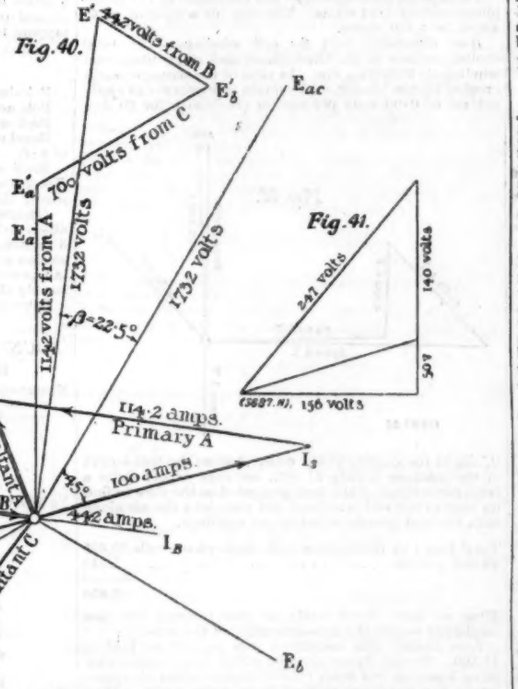

Fig. 41.

Calculation of permeance of path for leakage flux and single-phase winding.—The amount of the reactive drop in the electric furnace and connections was not exactly known when the machine was first laid out. In order, therefore, to allow a margin for adjustment, the three-phase winding was arranged so that there might be either 15 wires per slot or 16 wires per slot, and the single-phase winding so that there might be 15 turns per pole, or any smaller number. With 15 wires per slot (instead of 16) in the three-phase winding, and 15 turns per pole in the single-phase winding, the open-circuit low-tension voltage would be $232 \times 16 \div 15 = 247$. Even if the inductive drop in the furnace came out as high as 50 volts, it would still be possible to get the required output into the furnace at this voltage by making the inductive drop in the single-phase winding about 140 volts. The total inductive drop would then be about 190, and if the resistance drop were 156 the right-angled triangle (see Fig. 41) would be sufficiently well shaped for stable operation. If, however, the inductive drop in the furnace came out lower, the open-circuit voltage could be lowered either by using less than 15 turns on the secondary or by increasing the wires in the three-phase slots. These two expedients are somewhat different in their final effect. A reduction of the number of turns in the secondary is accompanied by a very considerable reduction in the inductance of the secondary winding, while an increase of the three-phase conductors has very little effect upon the inductance. The depth and width of the air-gap in the leakage path between primary and secondary (see Fig. 21) were adjusted to give about 140 volts inductive drop in the single-phase winding when the latter was carrying 340 virtual amperes in the 15 turns per pole.

The main path for the leakage flux around the single-phase winding is that across the narrow slit (0·45 cm. wide) that has been provided for this purpose between the long teeth. The radial length of the slit and its width were determined by some such calculation as that given below, which takes into account the amount of leakage occurring across the three-phase slot, the single-phase slot, &c. All that was necessary was to see that the radial depth (4·7 cm.) was great enough to carry the balance of the leakage flux required. The following is the final calculation.

Permeance (per cm. length of iron) of the leakage path for flux produced by single-phase winding (see page 422 of author's book for explanation of the method of calculation.)

Body of three-phase slot 3·7 ÷ 1·7 ...	= 2·2
Mouth of slot	= 1·1
Zigzag $0{\cdot}34 \times \frac{4}{2} \times \frac{1}{2 \times 0{\cdot}55 \times 1{\cdot}1}$ ...	= 0·56
Leakage air-gap 4·7 ÷ 0·45	= 10·4
Compensating conductor space 1·1 ÷ 1·8	= 0·61
Single-phase slot $\frac{1}{3} \times \frac{3{\cdot}8}{2{\cdot}3}$	= 0·55
	15·42

Twice the length of iron ... = 42 × 2 = 84 cm.
M.M.F. per slot = 340 × 5 × 1·41 × 1·257 = 3,020
15·42 × 84 × 3,020 ... = 3·92 × 10^6
End leakage ... ... = 0·4 × 10^6
Leakage lines per pole ... = 4·32 × 10^6

As the reluctance of the magnetic path is mainly in the air-gaps considered, the leakage flux (when the 15 turns are carrying single-phase current) will encircle all 15 conductors. The voltage generated will therefore be :—

Reactance volts in single-phase winding :—
= 0·707 × 2π × 50 × 15 × 4·32 × 10^{-8}
= 144 volts, or 144/30 = 4·8 volts per conductor.

This is with 15 turns per pole in the single-phase winding. If we reduce the number of conductors in one of the slots from 5 to 4, we do not affect the leakage across the remaining slots, but we cut down the volts per conductor in the one slot to 4·8 × 4/5 = 3·85 per conductor. The reactance voltage for 14 turns per pole is therefore

$$(20 \times 4{\cdot}8) + (8 \times 3{\cdot}85)$$

$$96 + 31 = 127$$

It is better to have the reactance rather too little than rather too much, because if it is too much it is impossible to get the full input, whereas if it is too little one can always reduce the input by increasing the length of the arc. We shall therefore take the figure 127 volts as near enough to 128 volts (the theoretical value given by Fig. 22) for practical purposes, and we cannot hope to predetermine the leakage flux with any great degree of accuracy.

Taps on single-phase winding.—It is sometimes desirable, after the metal is heated up in a refining furnace, to reduce the electrical input to such a point that the metal is maintained at an even temperature for some time. For this purpose it is usual to provide means of reducing the voltage in the furnace to less than one-half. In this case it was decided to put a tapping in each group of coils in parallel, at a point 5 turns removed from the outer terminal. These 5 turns will give 9·17 × 10 = 91·7 volts.

APPENDIX VIII.

METHOD OF CALCULATING THE NUMBER OF COMPENSATING TURNS.

Below is given the calculation of the flux across 1 cm. length of three-phase slot produced by unit magneto-motive force in the single-phase slot and effective in producing E.M.F. in the three-phase windings. It will be noted that the effective permeance of the body of the three-phase slot is taken at one-half the value taken above. This is for the reason that the conductors nearest the mouth of the three-phase slot do not embrace the whole of the flux in question. The total cutting of lines may be taken approximately as one-half the flux into all the conductors. Deducting 0·3 cm. for the insulation space at the top of the slot, the effective depth of slot is 3·4 cm.

Half body of three-phase slot ½ × (3·4 ÷ 1·7)	= 1·0
Mouth of slot	= 1·1
To rotor and back despite damper ...	= 0·56
	2·66

Flux threading through compensating winding per centimetre length of iron for unit M.M.F. in single-phase slot

= 2·66 × 19 = 50·5.

Leakage air-gap	= 10·4
Three-phase slot 3·4 ÷ 1·7	= 2·0
Half compensating coil slot = ½ (1·1 ÷ 1·8)	= 0·3
	12·7

From this it appeared that four compensating conductors (4 × 12·7 = 50·8) would embrace as much leakage flux as 19 conductors in the three-phase slots. The original design provided for 15 working conductors per slot plus four compensating conductors. When, however, it was found that the reactive voltage of the furnace was only about 28 volts, it was necessary to increase the three-phase conductors to 16. This cut down the compensating conductors from 4 to 3. To make up for this deficiency, a slightly unsymmetrical connection (described above) was made in the bringing out of the connections to the star point. This had the effect

* See Smith and Boulding: *Journal I.E.E.*, 1915, vol. 53, page 215.
† *Loc. cit.*

of substantially balancing the phases at full load, as will be seen from the figures given on page 725 *ante*.

APPENDIX IX.

Calculation of the Ampere-turns on the Field-Magnet.

It is necessary to make a calculation of the number of ampere-turns required at full load in order to preserve unity power factor on the three-phase side.

Single-phase armature ampere-turns.—The power factor of the single-phase load is 0·7, so that the demagnetising effect of the single-phase winding will be considerable. The best way of estimating the single-phase reaction is to rely upon experience with previous machines. As shown above, the average magnetising effect of a single phase load may be taken as from 0·65 to 0·75 of the magnetising effect of a load of the same current per phase on all three phases. On this machine we have a very effective damper, and may take the effect of the single-phase load as equivalent to about 0·7 of the corresponding three-phase load. In the low-tension winding we have 14/3 conductors per slot. The current per conductor is 340 amperes. The single-phase ampere-turns may therefore be taken as $\frac{14}{3} \times \frac{72 \times 340 \times 0{\cdot}43 \times 0{\cdot}7}{8}$ = 4,280 ampere-turns per pole.

Three-phase armature ampere-turns.—With 47 amp. per phase in the three-phase winding, the ampere-turns per pole are $47 \times 1{,}152 \times 0{\cdot}43 \div 8 = 2{,}900$ ampere-turns per pole.

Inductive drop in three-phase winding.—The permeance of the armature leakage path for leakage flux generated by the three-phase current can be calculated as follows :—

Body of slot $\frac{1}{3} \times (3{\cdot}4 \div 1{\cdot}7)$	...	= 0·66
Mouth		= 1·0
Zigzag		= 0·56
		2·22

Leakage flux across slots at load of 47 amp. :—

$2{\cdot}22 \times 42 \times 2 \times 16 \times 1{\cdot}41 \times 1{\cdot}257 \times 47 = 0{\cdot}25 \times 10^6$
End leakage ... ... $= 0{\cdot}15 \times 10^6$

$0{\cdot}4 \times 10^6$ lines per pole.

The working flux per pole $8{\cdot}6 \times 10^6$.

Inductive drop in three-phase winding :—

$$= \frac{0{\cdot}4}{8{\cdot}6} \times 6{,}000 = 280 \text{ volts.}$$

Resistance drop in three-phase winding :—

Resistance per phase ...		$= \frac{1}{3}(2{\cdot}34) = 0{\cdot}78$ ohm.
$0{\cdot}78 \times 47 \times 1{\cdot}73$ ...		= 64 volts

Resultant ampere-turns.—We are now in a position to draw the vector diagram that shows the relation between the various magnetising and demagnetising ampere-turns on the field magnet and armature. This is given in Fig. 42.

The conventions used in setting out this vector diagram are the same as those employed in Fig. 300 of the author's book referred to above. It will be seen that the ampere-turns of the armature are represented by the line I_a, which is 180 deg. out of phase with the terminal voltage vector E_t. This is due to the fact that the machine is running as a synchronous motor on unity power factor. The single-phase armature ampere-turns I_3 are set off at 45 deg. behind E_t, because the single-phase armature is supplying a generator load at power factor 0·7. From the calculation sheet we see that 5,420 effective ampere-turns are required on the field pole to generate E_g = 5,940 volts (obtained by setting off the impedance drop from the terminal volts E_t). The vector I_f is set off to represent 5,420 ampere-turns to scale at right angles to E_g. Then, setting off I_a and I_3 reversed we arrived at I_{fa}, representing 8,500 ampere-turns to be applied to the field pole to neutralise the single-phase and three-phase armature reactions and leave 5,420 effective ampere-turns to generate E_g. This graphic construction gives a result which agrees fairly well with the figures obtained on test. The exciting current required to give a mean power factor of unity (as will be seen later, the phases were not perfectly balanced) was 39 amp.; so that the applied field ampere-turns per pole were $39 \times 224 = 8{,}736$. The saturation of the poles may have been higher than expected, or the single-phase reaction rather more than 4,250 ampere-turns.

APPENDIX X.

Calculation of the Armature Copper Losses.

Single-phase coils.—The measured resistance of each of the 8 coils of 14 turns in the single-phase winding is 0·00442 ohm at 14 deg C. The crossing over of the three wires in parallel that make up the conductors of these coils had the effect of preventing any violent eddy current in the conductor as a whole; but there is still a small eddy current, owing to the fact that each wire has a depth of 0·6 cm. In the conductor lying nearest to the mouth of the slot, the eddy current, calculated from Field's curves,* give rise, to an additional loss equal to 55 per cent. of the normal copper loss; so that $K_d = 1{\cdot}55$. The values of K_d for all conductors are as follow :—

m_1 =	1·0
m_2 =	1·06
m_3 =	1·17
m_4 =	1·33
m_5 =	1·55
	5)6·11
	1·22

so that on the whole the eddy currents only increase the normal loss in the buried copper by 22 per cent. Allowing for a rise of resistance with temperature of 20 per cent. we have the normal loss (without eddies) in the 8 coils :—

$0{\cdot}00442 \times 1{\cdot}20 \times 340 \times 340 \times 8 = 4{,}900$ watts.

Of these $(42/92) \times 4{,}900 = 2{,}240$ watts are in copper buried in the slots. This must be multiplied by 1·22 to allow for eddy currents.

$$2{,}240 = 1{\cdot}22 = 2{,}740.$$

The losses in the copper of the end windings would be normally 2,660 watts. This is also somewhat increased by eddy-current losses, though not to the same extent as the copper in the slots. Allowing 10 per cent. increase due to eddies in the end windings, we get a total loss in the single-phase winding

$$2{,}740 + 2{,}926 = 5{,}666 \text{ watts.}$$

Three-phase winding.—The hot resistance of the three-phase coils is 2·24 ohms. The loss for a current of 47 amps. is 4,950 watts.

Heat dissipated from the end windings.—The total cooling surface of the three-phase and single-phase end windings is 86,000 sq. cm. In view of the strong draught created by the blower, each square centimetre can easily get rid of 0·09 watt per square centimetre for 30 deg.

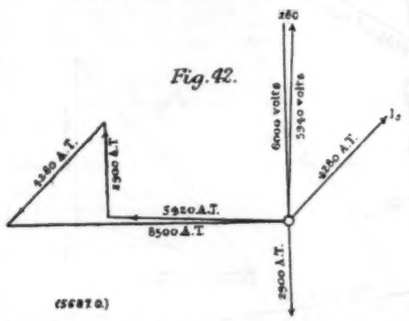

Fig. 42.

(58278)

C. rise of the outside of the coils. And as the half-length of the machine is only 21 cm., one may expect quite a large per centage of the heat generated in the slots to find its way to the end windings and pass into the air along with the heat generated in the end windings.

Total losses in three-phase and single-phase coils	10,610
$86{,}000 \times 0{\cdot}09$	7.740
	2,870

Thus we have 2,870 watts to pass through the slot insulation to join the heat generated in the iron.

Iron losses.—The calculated iron loss at no load is 11,500. To this figure must be added very considerable stray losses at full load. These losses cannot be calculated, but they are estimated at 4,000 watts. Thus the total losses to be dissipated from the surfaces of the iron are about :—

Iron loss	...	11,500
Stray losses	...	4,000
Buried copper	...	2,870
		18,370

The manner in which this loss can be dissipated from the surface of the stator for a temperature rise of 45 deg. C. is shown in the calculation given below. For further particulars of the method employed the author refers to his book (page 254).

Heat dissipated from working face of armature.—Peripheral speed 36 m. per second. Assuming a difference of temperature of 35 deg. C. between iron and air, we have :—

$$\text{Watts per sq.cm.} = \frac{35 \times (1 + 3{\cdot}6)}{333} = 0{\cdot}485.$$

$12{,}100 \text{ sq. cm.} \times 0{\cdot}485 = 5{,}900$ watts.

Heat dissipated by ventilating ducts.—Taking the coefficient $K_v = 0{\cdot}0007$ and the mean velocity in the ducts at 7 m. per sec., we have

$$h_v = 0{\cdot}0007 \times 7 = 0{\cdot}0049.$$

The total area of ventilating ducts, including the leakage air-gaps, is 83,600 sq. cm. Taking the mean difference in temperature between the iron and air in ducts at 20 deg. C., we have :—

$0{\cdot}0049 \times 20 \times 83{,}600 = 8{,}200$ watts.

Heat dissipated from outside of stator.

$38{,}700 \text{ sq. cm.} \times 0{\cdot}15 = 5{,}800.$

Total heat dissipated from stator for 45 deg. C. rise

$5{,}900 + 8{,}200 + 5{,}800 = 19{,}900$ watts.

Specification of 444-K.V.A. Synchronous Balancer Three-Phase to Single-Phase.

6,000 volts to 240 volts.
Reactive drop, 140 volts.
50 cycles, 8 poles, 750 r.p.m.
Amperes per terminal: three-phase, 47; single-phase, 2,750.

Stator.

(All dimensions in centimetres.)

Outside diameter		140
Inside diameter		91·5
Gross length		42
Air vents $6 \times 0{\cdot}7 =$		4·2
Net length of iron		34
Depth below slots		10

Stalloy iron.

72 three-phase slots each $1{\cdot}7 \times 4{\cdot}1$ (see Fig. 21, page 723).

Three-phase winding.—Sixteen effective conductors per slot. Room in slot for 19 conductors. Phases A and C have 19 conductors per slot, three of them forming part of compensating winding. Phase B has 16 conductors per slot. Size of conductors $0{\cdot}26 \times 0{\cdot}5$. Three taps to be brought out of each phase near the star point, viz., at 3, 6 and 9 turns respectively from the star point.

Single-phase winding, lying in 6 slots per pole, as shown in lay-out. Five conductors per slot, each consisting of 3 square wires in parallel. Size of wire 0·6 cm. square (= 0·35 sq. cm.). Fifteen turns per pole, 8 poles in parallel. The 3 individual wires are to be crossed over by special connectors at the joints. One tapping to be brought out of each coil.

Field Magnets,

8 poles.

Pole-body, $16{\cdot}5 \times 35$. Soft iron or very mild steel.
Pole arc, 24. Radial length of gap, 0·5.
Radius of curvature of pole face, 41·3.
Bevel extending over 3 cm., giving an air-gap at corner of 0·8.

Field winding.—224 (32×7 layers) turns per coil. Size of wire, $0{\cdot}35 \times 0{\cdot}35$ (say No. 10 B.W.G. square wire). Exciting current 40 amp., 50 volts.

Damper.—Eleven bars per pole, 9 drawn taper bars about 1·3 sq. cm. section. End rings each built up in 8 sections, one section per pole, bolted together, cross-section about 7·57 sq. cm. Damper rods held in dovetail grooves machined out of pole face: these are preferably skewed over the pitch of slots.

Poles should be laminated.

SOUND FIELDS AND SOUND ANTENNAS.*

By W. Hahnemann and H. Hecht.

Nomenclature.

ξ = instantaneous value of the displacement.
A = maximum value of the displacement.
$\dot{\xi}$ = instantaneous value of the velocity.
I = maximum value of the velocity.
p = instantaneous value of the pressure.
P = maximum value of the pressure.
V_0 and P_0 = corresponding values of volume and pressure.
V = maximum value of change of volume.
ρ = density.
C = compressibility factor.
κ = ratio of specific heats.
a = velocity of propagation.
n = frequency (cycles per sec.)
$\omega = 2\pi n$.
λ = wave-length.
ϕ = phase angle between pressure and velocity.
r = distance from source of sound.
L = intensity of sound per unit area.
L_R = intensity of sound for surface of sphere.
M = oscillating mass per unit area.
M_R = oscillating mass for surface of sphere.
b = "Damping factor."
δ = damping (i.e., log decrement).
w = electric resistance.
H = electric self-inductance.
e = electric voltage.
j = electric current.
Φ = velocity potential.
E = elasticity (modulus).

In the construction of acoustic apparatus we are led by theory to results which have very close electrical analogies and only by comparison with the corresponding electrical phenomena display their practical importance in acoustics.

In the following mathematical discussion we follow closely Lord Rayleigh's "Theory of Sound," and in the first section we set forth in an elementary and easily understood way some of his rigorously deduced results for the propagation of plane waves, extending these results by new deductions. Then in the second section the exact Rayleigh theory of spherical waves is applied for the region close to the the source of sound, in which case very close analogies to electrical results and phenomena appear. In the third section some practical deductions are drawn from the theory, and the fourth section is a recapitulation of the main results obtained.

§1. Plane Sound Waves.

By a plane sound wave we mean a flow of energy in the direction of the wave normal, such that the cross-sectional area through which the energy passes is constant; the *intensity* of such a wave is the energy which passes through unit area in unit time. Thus except

* Translation by Mr. Albert Campbell of paper published in *Physikalische Zeitschrift*, December 15, 1916.

* Proceedings of the American Institute of Electrical Engineers, 1905, vol. 24, p. 761.

for losses (due to friction for example) the intensity suffers no diminution as the wave progresses.

Let us consider, in a given medium, a cylinder of unit area cross-section with its axis in the direction of the sound ray and having a length equal to the distance travelled by the wave in unit time. It is clear that the intensity, as above defined, is equal to the amount of oscillation energy contained in this cylinder while it is acted on by the wave motion throughout its whole extent. This energy contact can be easily calculated. For this purpose we need only point out that the cylinder contains partly kinetic and partly potential energy, and that these must be equal in amount (strictly true only when the length of the cylinder is a whole number of half wave-lengths).

So in order to calculate the energy content we may consider the cylinder as containing only kinetic or only potential energy.*

As Rayleigh says, (Theory of Sound, vol. 2, page 18), "The total energy of the wave is equal to the kinetic energy of the whole mass of air concerned, moving with the maximum velocity to be found in the waves, or to the potential energy of the same mass of air when condensed to the maximum density of the waves."

Let ρ be the density, a the velocity of propagation of the wave in the medium, and I the maximum velocity of a particle. Then the intensity of a plane sound wave in the kinetic form is given by

$$L = \rho a I^2/2,$$

since a is the volume and ρa the mass of the cylinder considered.

If we introduce the maximum amplitude A instead of the maximum velocity I, then we have merely to remember that for every simple periodic function $I = 2\pi n A$, and then find

$$L = (2\pi n A)^2 . \rho a/2.$$

To find the expression for the intensity in potential form, let us consider the same cylinder but with rigid walls and closed by a movable piston which compresses the medium inside until the increase of pressure is equal to P, the maximum pressure amplitude of the wave. If the corresponding volume change of the medium in the cylinder be V, then the piston must have moved a distance equal to V, since the cross-section of the cylinder has been taken as 1. The mean force which the piston has to overcome in this movement is P/2, and hence the work done, which is equal to the intensity of the wave, must be given by

$$L = P V/2.$$

V must now be replaced by its value in terms of P, and here we must distinguish between the case of gases and liquids.

For *gases*, since the vibration is adiabatic, we have

$$(V/V_0)^\kappa = P/P_0,$$

where κ is the ratio of the specific heats, and V_0 and P_0 are the normal values of the volume and pressure respectively. If P is small compared with P_0, we can write

$$V/V_0 = \frac{1}{\kappa} . P/P_0.$$

Replacing V_0 by the volume a of the cylinder, we find for the intensity of the wave

$$L = \frac{a}{2\kappa} \cdot \frac{P^2}{P_0}.$$

The velocity of propagation (a) in gases fulfils the relation

$$a = \sqrt{P_0 \kappa/\rho}$$

and hence we can express L in the following two forms :—

$$L = \frac{\rho a^3}{2} \cdot \frac{1}{\kappa^2} \left(\frac{P}{P_0}\right)^2 \dagger$$

and

$$L = P^2/2 \rho a.$$

For *liquids*, in order to find the intensity in potential form, we use the relation

$$V/V_0 = C P,$$

where C is the modulus of compressibility, and hence

$$L = P^2 . a C/2.$$

In liquids the velocity of propagation is given by the equation

$$a = \sqrt{1/\rho C}$$

and by the help of this relation we can express L in the two following forms :—

$$L = \frac{\rho a^3}{2} (P . C)^2$$

and

$$L = P^2/2 \rho a,$$

the second of which is identical with the value obtained for gases.

For both compressible and incompressible mediums we can express the intensity of a wave in terms of the maximum values of the amplitude, velocity and pressure. Thus

$$L = \frac{\rho a}{2} (2\pi n A)^2$$

$$L = \frac{\rho a}{2} I^2$$

$$L = P^2/2 \rho a \ddagger$$

* Except in the case of a stationary wave in which a persistent local separation of kinetic and potential energy occurs.

† This expression was deduced by Wien (Wied. Ann., vol. 36, 1889) and used in his measurements of sound intensity.

‡ For each of these expressions the dimensions are those of power per unit area, namely $[M T^{-3}]$.

By combining the two expressions containing the velocity and pressure, we find for the intensity

$$L = \tfrac{1}{2} I . P,$$

an expression whose electrical analogy is the power given by an alternating current in phase with the terminal voltage, when I and P are the maximum values respectively. From the same two expressions we obtain

$$P = a \rho I,$$

or, in terms of amplitude instead of velocity,

$$P/A = a \rho . 2\pi n.$$

The quantity $a \rho . 2\pi n$ is a characteristic of the particular medium. We have named it the Sound Hardness (or Acoustic Rigidity) of the medium for the frequency n.*

§2. Spherical Waves.

The expressions for the intensity of a spherical wave and the behaviour in the immediate vicinity of the source of sound cannot be deduced in an elementary manner. Accordingly we shall use as far as necessary the exact theory given by Rayleigh and make the understanding of what goes on near the source easier by introducing new conceptions already familiar in electrical work.

Let us consider a spherical source of sound, whose surface is moving at all points in the same phase and with equal amplitudes. Such a sphere is called by Rayleigh a *radiator of zeroth order*.† When it radiates energy only into the external space, then according to Rayleigh (vol. 2, §280, page 112) the velocity-potential Φ of the diverging spherical waves at a distance r from the source of sound is given by the equation

$$\Phi = -\frac{Q}{4\pi r} \cos \omega (t - r/a),$$

in which Rayleigh's A is replaced by Q, standing for the maximum value of the current produced in the medium by the vibrating sphere, and Rayleigh's $k = n/a$ is replaced by ω/a, where $\omega = 2\pi n$, n being now the frequency (per unit time).

[If Δv be the alteration in volume of the sphere, for sine wave oscillations we have $Q = \pi n \Delta v$. The mass of the medium displaced in a half-period is given by the maximum value of the current

$$\int_0^{1/2n} Q \sin 2\pi n t \, dt = Q/\pi n$$

and this quantity of the medium is equal to the deformation volume of the sphere.]

From the velocity potential we can find the pressure and velocity of the medium at the place considered, thus

$$p = -\rho \frac{d\Phi}{dt} \text{ and } i = \frac{d\Phi}{dt}.$$

Carrying out the differentiations we have

$$p = -\frac{\rho n Q}{2r} \sin \omega (t - r/a)$$

$$i = \frac{Q}{4\pi r}\left[-\frac{\omega}{a} \sin \omega \left(t - r/a\right) + \frac{1}{r} \cos \omega \left(t - r/a\right)\right].$$

The relation between pressure and velocity becomes much clearer if we put

$$\omega/a = K \cos \phi \text{ and } 1/r = K \sin \phi,$$

or

$$\tan \phi = a/\omega r = \lambda/2\pi r,$$

and

$$K = +\sqrt{(\omega/a)^2 + 1/r^2} = +\sqrt{(2\pi/\lambda)^2 + 1/r^2},$$

where $\lambda = a/n$ is the wave-length.

If P and I are the maximum values of the pressure and velocity, then

$$p = -P \sin \omega (t - r/a)$$

and

$$i = -I \sin [\omega (t - r/a) - \phi],$$

where

$$P = \rho n Q/2r$$

and

$$I = \frac{Q}{4\pi r}\sqrt{\left(\frac{2\pi}{\lambda}\right)^2 + \frac{1}{r^2}}$$

Thus it is seen that there is a phase difference between the maximum values of the pressure and the velocity, the velocity lagging behind the pressure.

In order to find the intensity of the wave, if ξ is the displacement of a particle, we have

$L = n \int p \, \xi$ between the limits $t = r/a$ and $t = r/a + 1/n$, i.e.—

$$L = n \int p \frac{d\xi}{dt} dt = n \int p \, i \, dt = \tfrac{1}{2} I P \cos \phi,$$

an expression which includes the value for the plane wave as the special case when $\cos \phi = 1$. There is here complete analogy with the power for alternating current when the maximum values of current and voltage are I and P respectively, with a phase displacement ϕ between them.

The acoustical pressure equations, which are the real relations between pressure and velocity, may be obtained in the following way.

By differentiating the expression for the velocity we have

$$\frac{di}{dt} = \frac{Q}{4\pi r}\left[-\frac{\omega^2}{a} \cos \omega (t - r/a) - \frac{\omega}{r} \sin \omega (t - r/a)\right]$$

Hence

$$i r + \frac{a}{\omega^2} \frac{di}{dt} = -\frac{Q}{4\pi r}\left(\frac{\omega r}{a} + \frac{a}{\omega r}\right) \sin \omega (t - r/a)$$

$$= \frac{p}{\omega \rho} (\omega r/a + a/\omega r)$$

which gives

$$\frac{a \rho}{1 + (\lambda/2\pi r)^2} i + \frac{r \rho}{1 + (2\pi r/\lambda)^2} \cdot \frac{\partial i}{\partial t} = p.$$

In this form we recognise the perfect analogy with the well-known electrical voltage equation

$$w j + \Pi \frac{dj}{dt} = e,$$

where e, j, w and Π denote voltage, current, resistance and self-inductance respectively.

By use of the relation $\tan \phi = \lambda/2\pi r$, the acoustic pressure equation takes finally the simple form

$$a \rho \cos^2 \phi . i + a \rho \cos \phi \frac{\sin \phi}{\omega} \cdot \frac{\partial i}{\partial t} = p.$$

But we have seen that the intensity $L = n \int_0^{\frac{1}{n}} p \, i \, d$ by replacing p in the terms of i and carrying out the integration we obtain

$$L = \frac{a \rho}{2} \cos^2 \phi . I^2.$$

Comparing this with $L = \frac{1}{2} I.P \cos \phi$ already obtained, we get the following relation between maximum pressure and maximum velocity :

$$P = a \rho \cos \phi . I,$$

which includes the equation for the plane wave as special case for $\cos \phi = 1$. Now let this last relation be compared with the extended Ohm's Law of electricity

$$j = e/\sqrt{w^2 + (\omega \Pi)^2}$$

or (introducing angle of lag) $e = j \, w/\cos \phi$.

Close agreement is easily recognised with the acoustic equation, which may be called the Ohm's Law of acoustics, $a \rho \cos^2 \phi$ being the acoustic resistance. We notice further that the pressure, like the electrical voltage, can be resolved into two parts, a "Watt pressure" $P_w = a \rho \cos^2 \phi . I$, and a "Wattless pressure," $P_l = a \rho \cos \phi \sin \phi . I$, and that

$$P_w = P \cos \phi,$$

$$P_l = P \sin \phi.$$

Further, it is seen from the equation that the wattless pressure is due to a *co-oscillating mass* just as the wattless voltage is brought in by self-inductance. This mass of the medium is

$$M = \frac{a \rho \cos \phi \sin \phi}{\omega}$$

or

$$M = r \rho \sin^2 \phi,$$

where we have merely to keep in mind that $\frac{\partial i}{\partial t} = \frac{\partial^2 \xi}{\partial t^2}$.

We can therefore state that a divergent propagation of sound acts in acoustics as a resistance with self-induction in electricity : it postulates a lag of the velocity behind the pressure, it gives rise to a co-oscillating mass, and follows an acoustical law corresponding to Ohm's law, from which the power, watt-pressure, &c., can be similarly deduced.

For a sphere of radius R the total radiated power and the co-oscillating mass of the medium are found by multiplying by $4\pi R^2$ the expressions for L and M per unit area, thus

$$L_R = 4\pi R^2 a \rho \cos^2 \phi . \frac{I^2}{2}$$

$$M_R = 4\pi R^2 \rho \sin^2 \phi.$$

If we take the sphere to be massless and of such elasticity as to have the same natural period as the co-oscillating mass of the medium, then we can calculate the damping of this supposed case.

The log decrement :

$$\delta = \log_e \frac{A_{n+1}}{A_n}$$

$$= \frac{\Delta A}{A}$$

if ΔA is small compared with A_n. Since the energy is proportional to the square of the displacement amplitude (*i.e.* $F \propto A^2$) then $\Delta F \propto 2 A \Delta A$, or

$$\delta = \tfrac{1}{2} \Delta F/F.$$

Here $\Delta F/F$ means the ratio of the energy spent per oscillation to the undissipated energy of oscillation. Hence for this radiator

$$\delta = \tfrac{1}{2} . \frac{L_R}{n} \Big/ \tfrac{1}{2} M_R I^2 = \pi/\tan \phi.$$

In this equation we see a further corroboration of the agreement with the electrical quantities and relations. In electric terminology the equation gives the decrement for a self-inductance with resistance.

From the electrical voltage equation we can immediately write down the "damping factor"

$$b = w/2 \Pi$$

and the log decrement

$$\delta = b/n = w/2 n \Pi = \pi/\tan \phi,$$

We can similarly from the acoustic pressure equation directly obtain the decrement without having to work out the radiated energy and the "wattless" energy. Thus

* The quantity $a \rho$ plays an important part in connection with reflection and refraction. Rayleigh ("Theory of Sound," vol. 2, page 81), instead of sound hardness, borrows the expressions "rare" and "dense" from optics. As we consider mediums and vibrating bodies for simultaneously variable frequency, sound hardness seems a better designation.

† The order of the spherical harmonic is determined by the number of nodal lines : a radiator of zeroth order has no nodal lines, one of the first order has one, and so on.

$$\delta = \frac{a\rho\cos^2\phi}{2\pi a\rho\cos\phi\sin\phi/2\pi n} = \frac{\pi}{\tan\phi}.$$

It is reasonable to suppose, without further mathematical work, that a convergent propagation of sound in acoustics has its electrical analogy in a capacitance; and this is actually the case. If we write $-a$ for $+a$ in the velocity potential, the acoustic pressure equation becomes

$$a\rho\cos^2\phi \cdot \dot{s} + a\rho\cos\phi\sin\phi \cdot \omega\int i\,dt = p.*$$

From this we see that a convergence similarly to an electrical capacitance causes a lead of the velocity in front of the pressure and brings into existence an elastic force.

If we keep in mind that

$$\omega\int i\,dt = -\frac{1}{\omega}\cdot\frac{di}{dt},$$

a comparison of the two pressure equations shows that negative mass appearing in the mathematical equations must be physically interpreted as elastic force and *vice versa*. As limit between the divergent and convergent propagation we can treat the plane wave as an effect similar to that of the electric current in a pure (ohmic) resistance, and we find a corroboration of this in the relations deduced for the power and the pressure equation.

§3. Applications and Examples.

The foregoing deductions can have numerous applications in practical acoustics; we shall discuss two of these in particular.

1. *Acoustic Hardness.*—Suppose we have to compare two sources of sound of different frequencies with respect to their loudness, that is to say, their radiated energy. Let the measuring apparatus consist of a membrane (or diaphragm) whose natural frequency is so far above that of the highest of the two sound sources that it can be assumed to have constant sensitivity throughout the range of frequency investigated.† In general thin membranes are used for this purpose, their amplitudes being measured by optical, electromagnetic or other means.

If we wish to determine the sound intensity from the amplitude of vibration of the membrane, we must first make sure whether the membrane amplitude is measuring the variation of pressure or the movement of the medium. If we use a pressure-measuring receiver and find equal membrane amplitudes with a given frequency and its double, then, according to the results in §1, we conclude that the loudnesses are equal. If, on the other hand, the receiver measures movement and gives the same membrane amplitude when the frequency is doubled, we conclude that the loudness has increased fourfold. In every case we must endeavour to check which kind of receiver is actually being used. We should, however, remark of course that the two extreme cases can only be more or less approximately attained, since neither pure pressure receivers nor pure movement receivers can take up any energy from the medium, but must necessarily be perfect reflectors.

At the close of §1 we obtained as the acoustic hardness of the medium at frequency n the ratio of the maximum pressure to the maximum movement, where

$$(P/A)_{\text{medium}} = a\rho \cdot 2\pi n.$$

Let us compare with this the hardness of a membrane clamped at the rim and under uniform fluid pressure; this hardness is independent of the frequency (except for the lowering of the pitch). We have

$$(P/A)_{\text{membrane}} = \frac{5\,E\,d^3}{R^4},$$

where P is in kg./sq. cm. and A in cm., if E the modulus of electricity is in kg./sq. cm., d the thickness and R the radius in cm., while 5 is an empirical numerical factor depending on the nature of the clamping, &c. By a simple consideration, which best starts from the condition of equal hardness of the membrane and the medium, in which case the membrane to a certain extent vibrates as a part of the medium itself, we find a gradual transition from the acoustically harder membranes for pressure receivers to the weaker membranes for movement receivers. For in the first case the movement of the medium must gradually cease, while the pressure suffers no considerable change, and in the second case, as ultimately the membrane yields completely and pressure variation can no longer occur, the whole action resolves itself into pure movement.

A second practical case occurs when it is desired to use in any medium an arrangement for measuring loudness that has only been calibrated in another medium. For example, a steel membrane 0·3 mm. thick and of 40 mm. diameter has a hardness

$$(P/A)_{\text{steel membrane}} = 17.$$

The acoustic hardnesses of air and water for frequency of 500 $\sim$ per second are respectively

$$(P/A)_{\text{air}} = 0.12,$$

$$(P/A)_{\text{water}} = 440,‡$$

P being in kg./sq. cm. and A. in cm.

Thus if the membrane has been calibrated in air for a frequency of 500 $\sim$ per second and is to be used to measure sounds of the same frequency in water, we have to remember that in air it is acoustically hard, and hence a pressure receiver, but in water it is acoustically soft and therefore a movement measurer.

Another frequently occurring case is when bodies are immersed in the sound field, and it is desired that their presence shall influence the field as little as possible. Let us here assume that these bodies are small in comparison with the wave-length. The sound wave meets the bodies without suffering any considerable disturbance by them if the bodies are not acoustically softer than the medium; that is if, under the acoustic pressure of the medium in which they are, they perform movements of no greater amplitude than those of the medium itself.

As an example, let us consider a hollow cylinder of diameter D, wall thickness d, height H, and coefficient of elasticity E. To keep the treatment elementary, let us assume—as we shall find to be always sufficient in practice—that d is small compared with D, and that the basal area offers no elastic force in comparison with cylindrical area. Thus only the tangential component of the tension is taken into account, the radial and axial components being neglected.

With these simplifying assumptions the change ΔU in the circumference, due to an inner outer increase P of the pressure, is given by the equation

$$\Delta U = \frac{U}{2d\,.\,H}\cdot\frac{D\,.\,H\,.\,P}{E},$$

where D H P is the force tending to increase or diminish the circumference U of the cylinder; or if A is the radial amplitude,

$$\left(\frac{P}{A}\right)_{\text{metal cylinder}} = \frac{4\,E\,d}{D^2}.$$

Suppose the cylinder immersed in water. Then, if it is not to disturb the acoustic action in the water, we must make it as hard as or harder than a water cylinder of the same size. The volume of the cylinder is π H $D^2/4$, and its alteration of volume, in terms of the radial amplitude, is π A H D. If C is the coefficient of compressibility, then

$$P = \frac{1}{C}\cdot\frac{\pi\,A\,H\,D}{\pi\,H\,D^2/4}$$

or

$$(P/A)_{\text{water cylinder}} = 4/C\,D.$$

So if the metal cylinder is to be as hard as or harder than the water cylinder, we must have

$$4\,E\,d/D^3 > 4/C\,D$$

or

$$d/D \geqq 1/E\,C.$$

Hence for an iron cylinder in water

$$d/D \geqq \frac{1}{2\times10^6\times500\times10^{-7}} \text{ or } d/D \geqq \frac{1}{100},$$

that is to say, its thickness of wall must be at least 1 per cent. of the diameter.

In like manner approximate values can be calculated with sufficient accuracy for all cases that occur in practice, and we can always get a clear idea of the influence of such bodies. The calculations are of special importance when these bodies (or portions of them) form part of apparatus for sending out or receiving sound. As long as we work in air as medium, the necessary condition is always fulfilled; it is quite otherwise when we have to deal with acoustic behaviour in water, for which we have to assume at once a hardness 3,500 times that of air. The designer must here find special methods of procedure in order to satisfy the conditions demanded by theory.

2. *Radiator of Zeroth Order in Applied Acoustics.*—In §2 were given the relations connecting the radiating body of zeroth order with the medium, and as sounding body we considered a pulsating sphere kept in motion by an impressed periodic force. We obtained expressions for the phase angle between pressure and velocity, for the co-oscillating mass and for the damping. We will now give some numerical examples for a radiator of this kind.

The relation between the phase displacement at the surface of the radiator and its mass is given in terms of the wave-length by the equation

$$\tan\phi = \lambda/2\pi R.$$

For the determination of the watt-pressure, &c., it is convenient to construct a table of values of cos ϕ as follows:—

R/λ	1/10	1/5	1/3	1/2	1
cos φ	0.36	0.62	0.85	0.95	0.99

From this table we see not only that a source of sound, whose magnitude is from a half to a whole wave-length, can be considered as sending out plane waves in its vicinity, but also that with sources of sound of short wave-length we can take the waves as plane at any distance from a half to one wave-length. In both cases the pressure and velocity are practically in the same phase, and there is no idle vibrating energy worth taking into account.

Further, from what we have said, it follows that the mutual influence of two sound sources or the disturbing action of acoustically weak bodies (either being small compared with the wave-length) may be practically neglected at a distance of about half a wave-length. We have been able to prove all this repeatedly by experiment, and we intend to take it up again in a future paper.

For the co-oscillating mass of the medium the value has already been obtained:

$$M = 4\pi R^3\rho\sin^2\phi,$$

which by the help of the phase equation can also be written

$$M = 4\pi R^3\rho\,\frac{1}{1-(2\pi R/\lambda)^2}.$$

It will be seen from this that, for the case which is very frequent in practice, in which the radiator is small compared with the wave-length, the co-oscillating mass is independent of the frequency. Here

$$M_R << \lambda = 4\pi R^3\rho,$$

which means three times the volume of the radiator filled with the medium. For the damping of the simple "zero radiator" we found the log decrement

$$\delta = \pi/\tan\phi.$$

Introducing the size of the radiator instead of the phase angle, we have

$$\delta = 2\pi^2 R/\lambda.$$

from which equation the following table has been calculated.

R/λ	1/10	2/10	1/5	1/10	1/20
δ	2	1	0.2	0.1	0.02

From the decrement equation it is seen that the log decrement for a given "zero radiator" is proportional to the frequency, unlike the radiation system of radio telegraphy with electromagnetic waves, in which the radiation decrement varies approximately as the cube of the frequency. The reason for this is that the radiation systems of electromagnetic waves are in general of the first order; for acoustic systems of the first order the damping likewise falls off by a higher power.

"Zero radiators" can also be used as receivers of sound; we may borrow a term from radio telegraphy and state that they form sound antennas and possess analogous properties.

Up to this point we have taken as radiator a pulsating sphere, itself without mass and kept in vibration by a periodic force. In practice, for a body of zeroth order, one does not use a pulsating sphere, but a vibrating membrane, which may be considered as clamped to the rim of a cylindrical vessel so as to form one end surface, while between the membrane and the other (acoustically hard) end surface is introduced the exciting force, for example by means of an alternating current electro-magnet. The cylindrical walls must of course also have sufficient acoustical hardness. The inside of this vibrator must be filled with a medium which is essentially softer acoustically than the outer medium. Otherwise we should have an elastic effect of the inside medium in addition to the inertia effect of the outer, as can be seen from §2, which dealt with converging waves.

The whole vibrating mass is made up of two parts, the mass of the membrane (including the parts fixed to it for the purpose of generating the periodically applied force) and the co-oscillating mass of the medium; whilst the constant elastic force is (entirely) in the membrane. Thus the whole forms a dynamical vibratory system whose natural oscillation is given by the elastic force and these masses. If it is desired to radiate the greatest amount of energy with the minimum expenditure of applied periodic force, then we must bring the frequency of the applied force into tune with the natural frequency of the system. In this way we attain the condition that the impressed pressure amplitude (generating energy) is in phase with the velocity amplitude of the sound energy going out from the membrane. The amplitudes of the elastic force are then equal and opposite to the sum of the inertia forces of the mass itself and the co-oscillating mass of the medium.

The damping of a radiator of this kind is smaller than for the case already given; it can be calculated from the ratio of its own mass to the associated medium mass, which latter was alone taken account of in the former case.

§4. Summary.

The preceding discussion has shown that between an acoustic field and electrical phenomena there exist very close formal relations, and that electrical conceptions can with advantage be transferred to acoustics.

A plane acoustic field is analagous to a pure resistance, a convergent field to a capacitance with resistance, and a divergent field to a self-inductance with resistance.

Just as the electric voltage is, in the three cases, in the same phase, lagging or leading with regard to the current, so in the three acoustic cases the pressure has a similar relation to the velocity.

Similarly for power, which when electrical is equal to the product of the voltage and current and the cosine of the angle of phase difference, we have in acoustics to replace voltage by pressure and current by velocity.

As in electricity the ratio of voltage to current is resistance, so the ratio of pressure to velocity is acoustic hardness. Acoustically hard bodies admit only states of pressure but no velocities and behave analogously to electrical insulators; while acoustically weak bodies show the opposite properties and resemble good conductors, for when brought into a sound field they tend to annihilate the field in their neighborhood. The method of calculating the acoustic hardness of various bodies and mediums has been indicated.

It follows from the investigation that sound transmitters and receivers are in close connection with the surrounding medium; the degree of connection depends on the ratio of the size of the acoustic source to the wave-length and from it the damping and the increase of effective mass can be calculated.

Finally some remarks are made upon a "zero radiator" which can be used in actual practice in contrast with the intentionally simple transmitter assumed in the theory.

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* The displacement is here written $\int i\,dt$ instead of ξ in order to bring out more clearly the agreement with the electrical equation.

† The other method of choosing the natural frequency lower than that of the sources is only possible with the very greatest precautions since of course any coincidence with overtones must be avoided. Although this rule is so self-evident it is often transgressed.

‡ Water is thus about 3,500 times acoustically harder than air.

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ELECTRICAL APPARATUS.

119,736. The Electrical and Ordnance Accessories Company, Limited, Birmingham, and N. G. Langrish, Birmingham. Electric Motor Starters. (9 *Figs.*) November 10, 1917.—This invention relates to hand-operated electric motor starters. According to the invention, which is applicable either to a barrel type or a faceplate type of starter, the loose handle member carries one member of a one-way clutch device, the other member of which is operated, when the said loose handle makes its backward movement relatively to the barrel or contact arm, in order to actuate means for opening the circuit-breaker. The operating handle is rigidly attached to a shaft 1 passing through the starter case 2, said shaft being in alignment with and forming a bearing for the barrel shaft 3, as shown in Fig. 2. To the handle shaft is fixed a disc 5 provided with a radial arm 6 having a downwardly projecting lug 7 at its outer end engaging, and having a limited idle rotary movement, between two stops 8, 9, carried by a plate 10 attached to the barrel shaft 3. A spring 12 carried by the plate 10 acts upon the lug 7 of the handle member so as to move the same against the stop 8. When the handle is moved in a direction to cut out

Fig. 1.

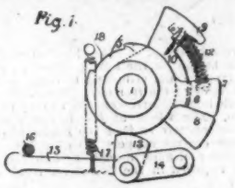
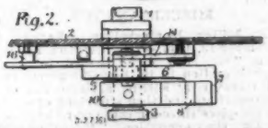


Fig. 2.



the starting resistance this spring 12 is first compressed during the idle movement of the handle until the lug 7 engages with the second stop 9, when the handle and barrel will move together to cut out the resistance. The disc 5 engages by its periphery with a one-way friction clutch device, which may consist of a sector-like pawl member 13 pivoted to a swinging link 14 and carried by an arm 15 normally pulled against a stop 16 by means of a spring 17. During the movement of the handle for cutting out the resistance, the edge of the disc 5 wipes past the clutch device 13, but when the handle is released and makes its limited return movement between the two stops the friction causes the clutch to operate, the pawl member 13 partially rotating and moving its arm 15 away from the stop against the action of the spring. This movement of the arm is adapted to operate a circuit breaker, so as to open the circuit independently of the movement of the barrel member. The friction disc 5 is gapped away for a short distance at 18 so that when the starter is in its full "on" position this gap comes opposite to the clutch device 13, which latter is therefore not operated by the return movement of the handle and the circuit-breaker remains closed. (*Accepted October 23, 1918.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

119,629. A. Goodwin, Southwark, London. Shaft Pulleys. (3 *Figs.*) April 19, 1918.—A pulley according to the invention is constructed with a rim *a* made of strip metal in one or more lengths bent to a circular shape and arranged with the adjacent ends butting against each other and with combined spokes and hub formed of three or more lengths of strip or bar metal, each bent to a shape to form one-half of two spokes arranged at an angle to one another less than two right angles with an intervening portion adapted to form part of the hub, the said lengths being assembled together to form a central divided hub and three or more radial two-part spokes, the outer ends of the two parts of each spoke being riveted to the pulley

Fig. 1.

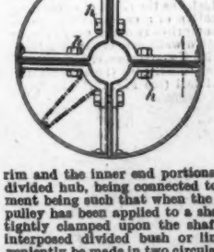
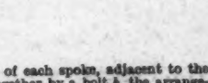


Fig. 2.



rim and the inner end portions of each spoke, adjacent to the divided hub, being connected together by a bolt *h*, the arrangement being such that when the bolts are tightened up after the pulley has been applied to a shaft, the divided hub will become tightly clamped upon the shaft either directly or through an interposed divided bush or liner. The pulley rim may conveniently be made in two circular parts and the outer ends of two of the two-part spokes be riveted to the part rims at opposite sides of the joints thereof, so that upon removing the bolts that are used for drawing the inner end portions of each spoke between each other, the pulley can be split to admit of its ready application to a shaft without disturbing such shaft. (*Accepted October 16, 1918.*)

MINING, METALLURGY, AND METAL WORKING.

119,509. B. Talbot, Middlesbrough. Compressing Ingots. (2 *Figs.*) September 29, 1917.—To remove the cavity or piping which normally forms near the top of a steel ingot and to diffuse the segregation it has been proposed to compress the ingot, either while in its mould or after removal, by rolling or by hydraulic presses, either while the interior of the ingot is still in a molten or plastic state or after it has been re-heated. According to the invention, and in order to secure the minimum amount of waste or crop end to be discarded, the pressure is applied while the upper part of the ingot is at a higher temperature than the lower part. For this purpose the ingot is preferably cast in a mould in which an annular chamber is provided at the upper

Fig. 1.

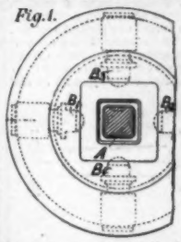
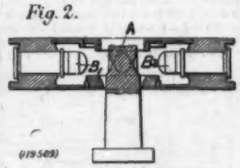


Fig. 2.



end of the mould filled with molten slag. Pressure is applied in known manner to form depressions in the opposite sides of the ingot, and these depressions should extend at least as far as the part at which the crop will be made. The applied pressure causes the impurities to be forced into the top of the ingot, which is in a more plastic condition than the lower parts, and the segregation of the impurities is more complete than in other known processes for obtaining this result. A is the ingot, B^1, B^2, B^3, B^4 hydraulic rams, B^1 being opposite B^2 and B^3 opposite B^4. The operative faces of the rams are formed of the dimensions and curvature suited to produce the required depressions in the ingot A. The depressions are shown in the dotted lines of Figs. 1 and 2. (*Accepted October 16, 1918.*)

119,504. Blast Furnaces and Equipment, Limited, and F. Ritson, Westminster. Blast Furnaces. (2 *Figs.*) September 28, 1917.—This invention has reference to charging hoppers of blast furnaces. The hopper is constituted of a primary portion A and a secondary portion B, each of segmental construction. The segments 1 of the primary portion A are provided with flanges 2 by means of which they are connected together. The segments 3 of the secondary portion B are provided with flanges 4 for a similar purpose. Each of the segments 1 is provided at its lower end and on its upper face with a groove 5, and each of the segments 3 is provided at its upper end and on its under face with a flange 6. The arrangement is such that when the segments 1, 3 are assembled, the primary portion A has a continuous groove at its lower end and on its upper face

Fig. 1.

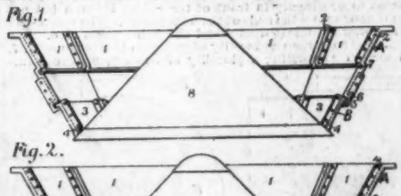
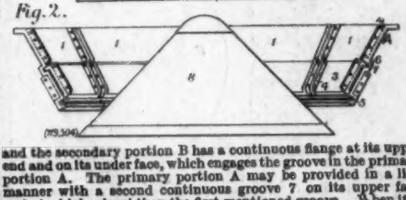


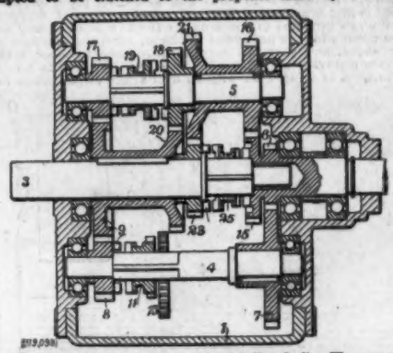
Fig. 2.



and the secondary portion B has a continuous flange at its upper end and on its under face, which engages the groove in the primary portion A. The primary portion A may be provided in a like manner with a second continuous groove 7 on its upper face and at a higher level than the first-mentioned groove. When it is desired to remove the bell 8 or provide a new sealing therefor, the several segments 3 constituting the secondary portion B are disconnected from one another and their flanges 6 lifted out of the groove 5 in the primary portion A. The segments 3 are then removed from the blast furnace or their flanges 6 are temporarily engaged in the groove 7 in the primary portion A. The upper faces of the primary and secondary portions A, B, when in position, are in one plane so that no obstruction is offered to the passage of the charge into the furnace. (*Accepted October 16, 1918.*)

MOTOR ROAD VEHICLES.

119,098. T. A. N. Leadbetter, Hale, A. L. K. Gilchrist, Lytham, and W. H. Tate, Ashton-on-Mersey, Manchester. Speed-Gear Mechanism. (4 *Figs.*) September 26, 1917.—The invention provides a variable speed gear-box suitable for motor-driven vehicles, and is directed to that type of gear-box having driving and propeller shafts in line and lay shafts parallel thereto, the lay shafts being permanently geared to the driving shaft and having loose gears permanently in mesh with other gears on the propeller shaft, means being provided for clutching any of the loose gears on the lay shafts to those shafts in order to obtain the change speeds. The gear mechanism is housed within a box 1, the driving shaft and propeller shaft 3 being axially in line, lay shafts 4, 5 being disposed on either side. For the first speed, a pinion 6 integral with the engine shaft meshes with a spur gear 7 keyed on the lay shaft 4, on the other end of which shaft is loosely mounted a pinion 8 permanently in mesh with a spur wheel 9 keyed on the propeller shaft 3. The pinion 8 is provided with clutch projections, and a clutch element 11, slidable axially on the lay shaft 4 and keyed rotatively thereto, is moved into engagement with the clutch projections on the pinion 8, and thus permits the lowest speed drive to take place by way of the engine shaft, primary lay shaft 4, pinion 8 and spur wheel 9 to the propeller shaft 3. The secondary lay shaft 5 is driven from the engine shaft by a spur wheel 16 on the latter, of approximately equal diameter with a spur wheel 16 on the lay shaft. The other end of the secondary lay shaft is provided with two loose pinions 17, 18, adapted to be rotatively and alternatively clutched to the shaft 5 by the longitudinal movement of a secondary clutch element 19. These loose gears on the secondary lay shaft 5 are permanently in mesh one, 17, with the spur wheel 9 and the other, 18, with another spur wheel 20 on the propeller shaft 3. Consequently, for the second and third speeds, the drive is taken by way of the engine shaft, secondary lay shaft 5 and either one or other, 17, 18, of the clutched pinions on the lay shaft, through that spur gear 9 or 20 with which either of the clutched pinions is in gear, and so to the propeller shaft 3. In addition to the spur wheel 16 on the secondary lay shaft 5, is another slightly larger gear 21 permanently in mesh with a pinion 23 running loosely on the propeller shaft 3, this pinion 23 having dog projections and being adapted to be clutched to the propeller shaft by a clutch

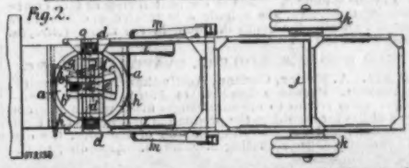


element 25 rotatively keyed to the propeller shaft. The opposite side of this clutch element has a series of dogs engaging corresponding dogs on the gear 15, so that, alternatively, the clutch element 25 may couple the engine shaft 2 directly to the propeller shaft for the fourth speed, or the loose pinion 23 to that shaft for the fifth speed, which is then taken from the engine shaft by way of the gears 15, 16, the secondary lay shaft 5, gear 21, and the clutched pinion 23 on the propeller shaft to that shaft. (*Accepted October 2, 1918.*)

119,132. The Lacre Motor Car Company, Limited, Letchworth, and J. S. Drewry, Letchworth. Tractors and Trailers. (2 *Figs.*) October 26, 1917.—This invention relates to trailers of the single-axle kind used in connection with self-propelled motor vehicles or tractors and capable of being attached to and detached from a tractor at will. The rear portion of a tractor, which is to co-operate with the front end of a trailer, is provided with a flat deck *a* on which is secured a trough-like socket *b* shaped to accommodate a downwardly projecting pin which is attached to the underside of the front portion *d* of the trailer and serves as a pivot when the trailer turns relatively to the tractor. The socket is formed with an opening *g* which gradually widens towards the rear. Mounted to move transversely of the socket passage is a sliding bolt *f*, which is arranged to hold the pin in working position. A lever *g*

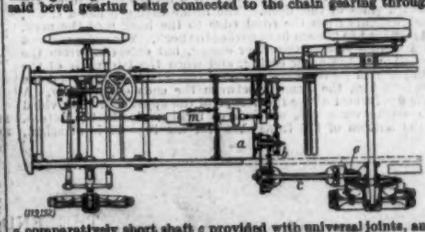
Fig. 1.

Fig. 2.



positively operates the bolt. Surrounding the socket is a circular runway *h*, with which co-operate parts carried by the trailer. Branching out of the runway at each side thereof are two rearwardly extending and downwardly sloping tracks *i*. The trailer, which consists of a flat platform supported at or near its rear end on a horizontal axle *j* mounted on road wheels *k*, is furnished near its front end with supports *m* in the form of hinged struts. Arranged one on each side of the pin and mounted on the underside of the trailer platform are two rollers or wheels *o*, which are hereinafter termed lifting wheels and are set at the same distance apart as are the two sloping tracks *i* leading to the runway *h*, so that the said lifting wheels *o* are able to ride up the tracks when the tractor and trailer are brought together, and pass on to the runway *h* along which they can roll when the coupled up trailer turns about the axis of its pin. (*Accepted October 2, 1918.*)

119,192. Edison Accumulators, Limited, London, and J. F. Monnet, London. Electrically-Propelled Road Vehicles. (2 *Figs.*) March 12, 1918.—The invention relates to motor road vehicles propelled by electrical power. According to one feature of the invention, the electric power plant consists of two motors *a*, *a* located in about the middle of the chassis, each motor driving one of the rear wheels independently of the other through chain gearing *b* at the motor and bevel gearing *c* at the wheel, said bevel gearing being connected to the chain gearing through

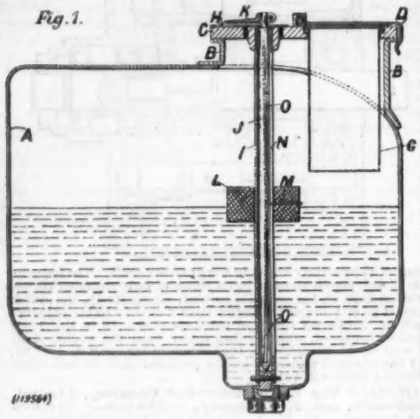


a comparatively short shaft *c* provided with universal joints, and, according to another feature of the invention, the electric controller *m* is located adjacently to the said motors and about midway between them and according to a third feature of the invention, the storage battery which has usually heretofore been placed about in the position where, according to the present invention, the power plant is disposed, is placed partly in a compartment under the driver's seat, the remainder being in a compartment in front of the dashboard, as, for instance, beneath a bonnet there situated. (*Accepted October 2, 1918.*)

119,564. R. W. Maudsley, and the Standard Motor

Company, Limited, Foleshill, Coventry. Liquid-Fuel Tanks. (2 *Figs.*) October 22, 1917.—This invention relates to fittings for liquid-fuel tanks. According to this invention there is combined with a detachable cover plate for a tank for liquid fuel a fuel-level indicator and a tank-filling aperture, which are situated side by side on the said cover plate, but notwithstanding are distinct from one another, so that a single opening, so provided in the tank for the two fittings, may be large enough for the passage of the hand, when the cover plate is removed, and that fuel may be introduced into the tank without removing the level indicator or employing it as a fuel conduit. A is a fuel tank with an oval orifice large enough to

Fig. 1.



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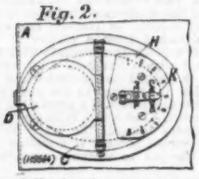
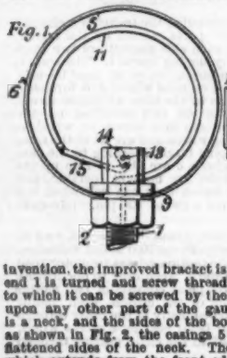


allow the passage of the hand and surrounded by a wall B. A detachable cover plate C is bolted over the orifice and carries a hinged filler cap D. A strainer G is dropped into position under the filler cap. A fuel-level indicator dial H is fixed on the cover plate, and depending from the underside of the latter into the liquid is a tube I plugged at the bottom to form a bearing for a rotatable spindle J, which carries an index finger K at its upper end over the dial H. A float L is provided with a pin M which projects through a longitudinal slot N in the tube I into a helical slot O in the spindle J. Thus as the float L rises or falls on the surface of the liquid, the spindle J is rotated and the index finger K indicates the depth of liquid in the tank. (*Accepted October* 16, 1918.)

STEAM ENGINES, BOILERS, EVAPORATORS &c.

119,643. A. Mellor, Carlton, Nottingham, and R. Smith, Nottingham. Pressure Gauges. (4 *Figs.*) July 31, 1918.—This invention relates to pressure gauges fitted with a Bourdon tube, and has for its object the production of a bracket or block in one piece, and the mounting thereon of the tube, the dial finger and the finger actuating mechanism. According to the

Fig. 1.



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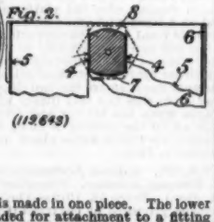
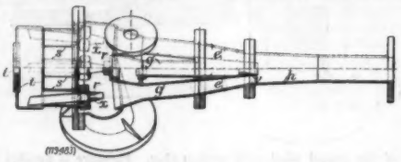


invention, the improved bracket is made in one piece. The lower end 1 is turned and screw threaded for attachment to a fitting to which it can be screwed by the head 2 without putting strain upon any other part of the gauge. Above the head 2 there is a neck, and the sides of the bottom of the neck have flats 4, as shown in Fig. 2, the casings 5 and 6 being slotted to fit the flattened sides of the neck. The inside casing 5 has a slot 7, which extends from the front edge to the back 8 of the neck, and is shaped to fit such back part of the neck. The outer casing 6 has a similar slot to the inner casing, but extending from the back edge of the outer casing, and when the two parts of the casing are in position and fastened together they fit round the neck and lock the bracket between the ends of the slots. A collar 9 is formed above the neck, and the upper part is provided with a transverse slot, which is at right angles to the flats 4. At the bottom of the transverse slot the tube 11 is attached, and is in communication with a hole, drilled through the bracket. The upper part of the bracket is drilled for the dial finger axle 13 and inside the transverse slot there is a lever or eccentric 14 fixed upon the axle 13 and connected to the free end of the tube 11 by a link 15. (*Accepted October* 16, 1918.)

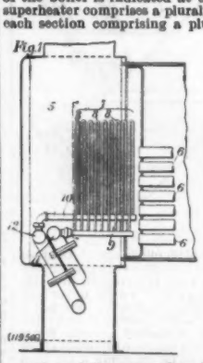
119,483. D. B. Morison, Hartlepool. Ejector Apparatus. (10 *Figs.*) June 29, 1917.—This invention relates to ejectors of that general character wherein a plurality of jets each operating in conjunction with its own combining tube are arranged in parallel and all the combining tubes discharge to a common outlet. Apparatus in accordance with this invention comprises two ejector sections arranged in one unit; the first section consists of a plurality of ejectors each comprising a nozzle *x* and combining tube *e* operating in parallel, leading from a suction chamber *r* and arranged around the axis of an ejector comprising a nozzle *v* and combining tube *h* which forms the second section, the discharge from the ejectors of the first section being around or forming an annulus around the inducing fluid nozzle of the ejector of the second section so as to convey the discharge fluid thereto for further compression. The axes of the ejectors in the



first section preferably converge to a point in advance of the nozzle of the ejector forming the second section, said point being on the axis of the last-mentioned ejector. The nozzles of the ejectors may be supplied with operating fluid of any kind, but when supplied with steam, a steam supply chamber *t* may be formed at a distance from the suction chamber *r* of the first section in order to reduce the heating effect which the steam has on the fluid in the suction chamber of such section, and the connections *s* between the two chambers may be of tubular form and contain steam supply pipes leading to the nozzles. With the same object, there may also be an air space between the combining tubes of the ejectors in the first section and the fluid supply passage to the ejector in the second section, the apparatus being conveniently divided or constructed in parts with the object of facilitating manufacture. (*Accepted October* 16, 1918.)

119,506. J. E. Slack, London. Steam Superheaters. (3 *Figs.*) September 28, 1917.—This invention relates to steam superheaters for use in connection with multi-tubular boilers. According to this invention the heating tubes of the superheater are arranged in sections, each section of tubes being connected to intermediate manifolds or headers which are in turn removably connected with main intake and outtake headers or steam connecting pipes and each section of tubes is located in the smoke-box in a well-known manner so as not to interfere with the passage of a cleaning brush through the boiler tubes, the tubes of each section of the superheater occupying positions adjacent to or directly in front of the spaces between but not in front of or across the ends of the boiler tubes. The smoke-box of the boiler is indicated at 5 and the boiler tubes at 6. The superheater comprises a plurality of sections of heater tubes 7, 7, each section comprising a plurality of tubes 8, 8, here shown

Fig. 1.



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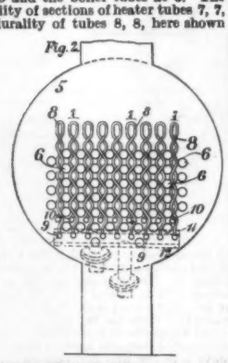


as being of the return-flow type with their inlets and outlets located adjacent to one another and respectively connected to a plurality of intermediate manifolds or headers 9, 10, arranged horizontally at the bottom of the superheater. The intermediate headers 9, 10, occupy positions in the smoke-box 5 parallel with the boiler tubes 6, and are in turn removably connected to the main steam intake and out-take header 11, 12, which are so located as to be out of the direct path of the boiler flue gases. The heater tubes 8 are arranged vertically so as to occupy the vertical spacing between the boiler tubes and are respectively connected to their intermediate headers 9, 10, which are located at the bottom of the superheater. In some cases it may be found convenient so to connect the heater tubes 8 with the intermediate headers that the former will occupy the diagonal spacing between the boiler tubes. Alternatively, the heater tubes 8 may be arranged horizontally in which case the intermediate headers to which they are connected may conveniently occupy a vertical or approximately vertical position at one or both sides of the superheater. (*Accepted October* 16, 1918.)

SHIPS AND NAUTICAL APPLIANCES.

119,633. J. C. Grant, Barnes, London. Ship Construction. (3 *Figs.*) May 21, 1918.—The present invention relates to ocean-going ship construction of ferro-concrete or ferro-cement. The invention consists in combining with such a longitudinal reinforced lattice girder of reinforced concrete transverse reinforced concrete frames extending completely around the ship placed at suitable intervals and connected by suitable longitudinal stiffening members of reinforced concrete running the whole length of the ship, and constituting an outer framework adapted to carry the ferro-concrete forming the sides of the ship. The upper member *a* of the lattice girder extends the whole length of the ship at the level of the deck and the lower member *b* forms the keelson. Vertical members *c* are provided at distances of about 12 ft. apart, the squares thus formed being

Fig. 1.

Fig. 2.

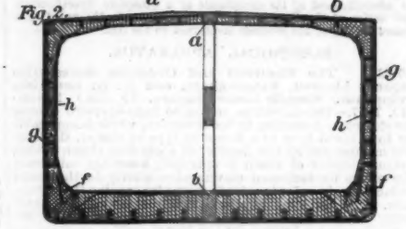


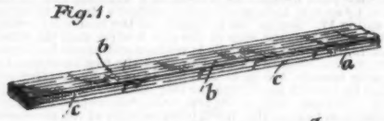
Fig. 3.

provided with cross braces *d*, *e*. The ship frames *f* are of ferro-concrete, and are built into the lattice girder as illustrated at Fig. 3, and the longitudinal stiffening members *g* are fitted in grooves on the outside of the frames *f*. The ship's walls *h* may be either of a single layer of ferro-concrete or may be double or of cellular structure. The whole of the lattice girder may be filled in with ferro-concrete so that the lattice girder forms an exceedingly strong central support dividing the body of the ship into two halves and allowing considerable reduction in the quantity of steel required in the transverse frames. (*Accepted October* 16, 1918.)

MISCELLANEOUS.

119,582. A. Miller, Dunfermline. Expanded Metal. (2 *Figs.*) December 13, 1917.—This invention has reference to the well-known "expanded metal" used in ferro-concrete structures. The invention in its broadest aspect consists in vertically and transversely slitting a single bar of metal of appropriate cross-section, and then stretching or expanding the same so that a one-piece three-dimensioned reticulated structure is obtained. By the expression "three-dimensioned" is designated a structure of expanded metal without joints having length, breadth and substantial volume in the direction of its thickness, or in other words a one-piece expanded metal structure of open girderlike formation. The production of expanded metal in accordance with this invention is effected by providing a bar *a*

Fig. 1.



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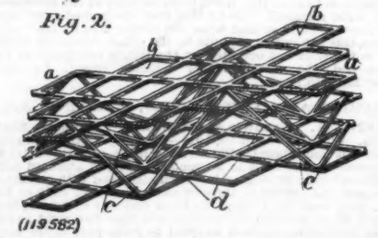

with longitudinal slits *b* formed vertically therein and extending completely through the metal, each row of slits breaking joint with or being arranged in staggered relation to the slits in adjacent rows. The bar is also provided with horizontal transverse slits *c* arranged in similarly staggered relation, these transverse slits crossing or intersecting the vertical slits. The bar is now subjected to a stretching action which has the effect of expanding the metal and results in the formation of a one-piece expanded metal element or structure which comprises two or more approximately flat and continuous reticulated walls connected by lateral ties *d*. It will be seen that with the arrangement of crossed slits *b* and *c* the intervening metal constitutes the said strand when the bar is expanded or stretched (see Fig. 2). (*Accepted October* 16, 1918.)

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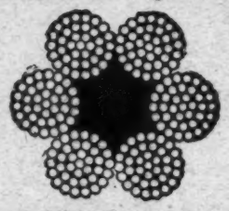
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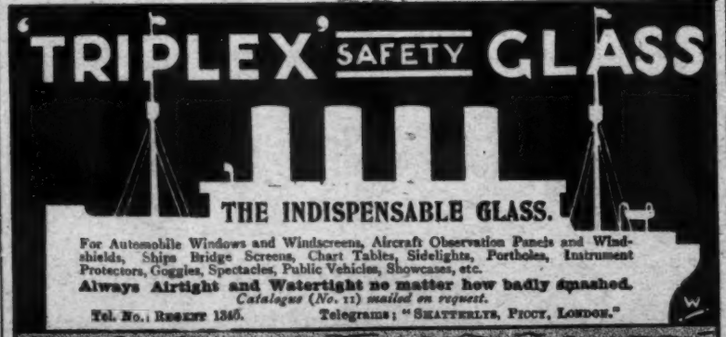
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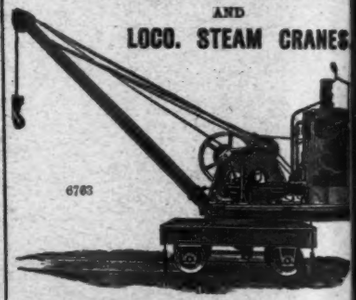
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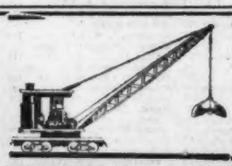

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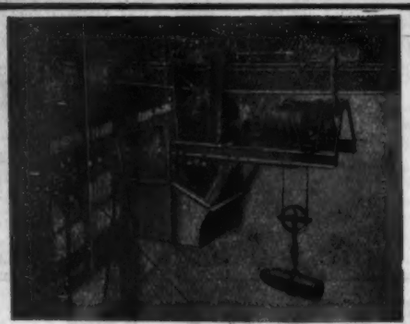

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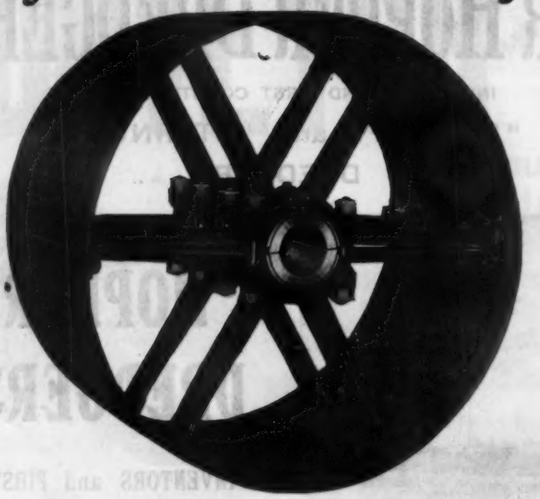

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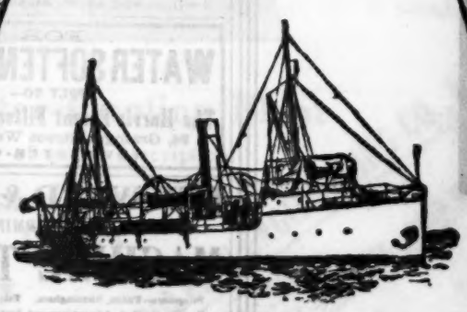

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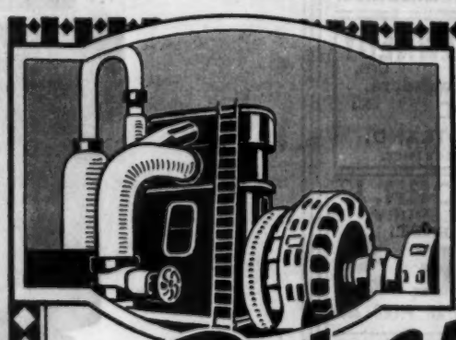

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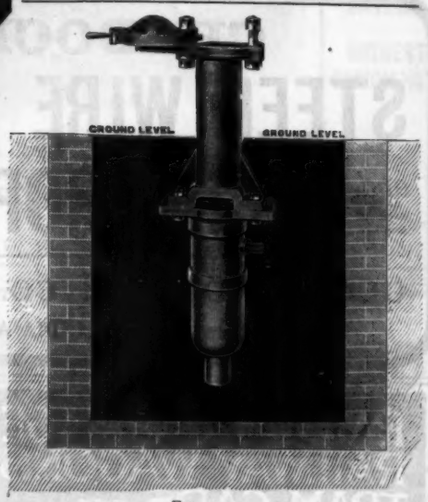

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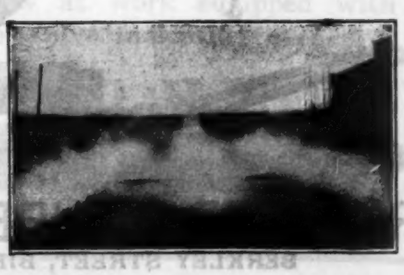

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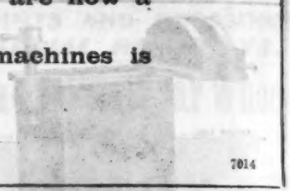

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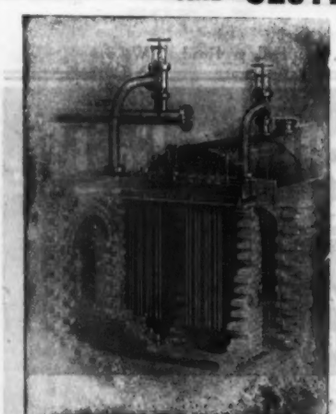

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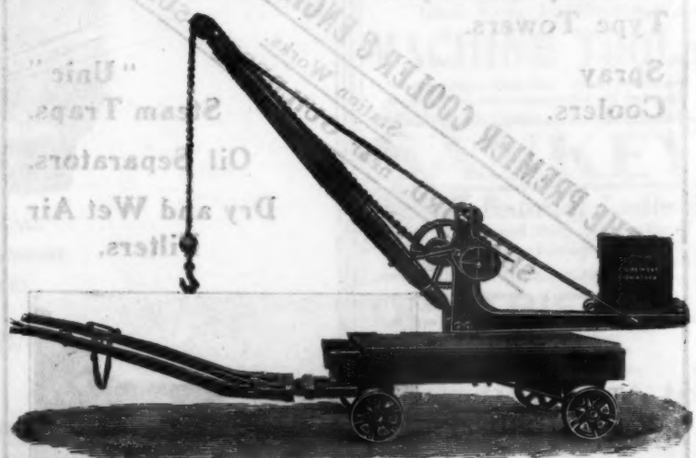

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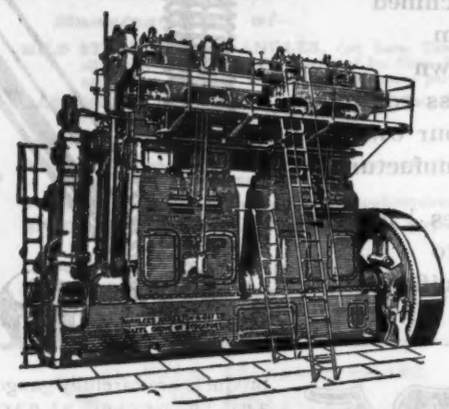

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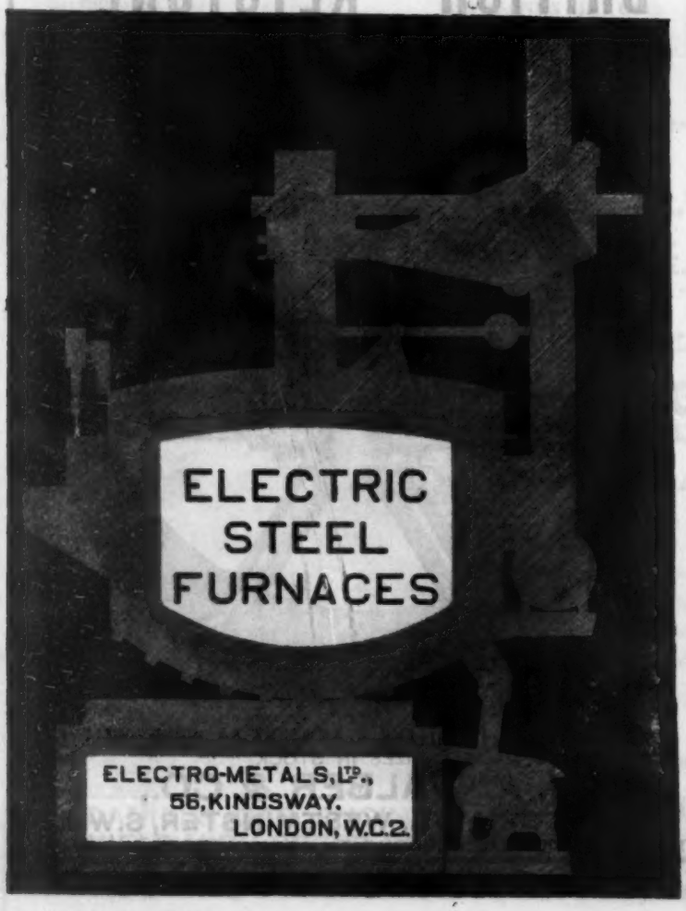

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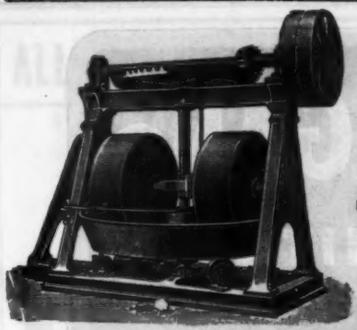

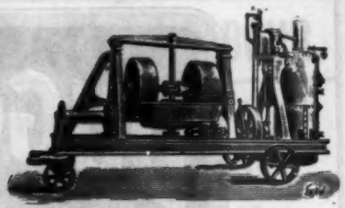

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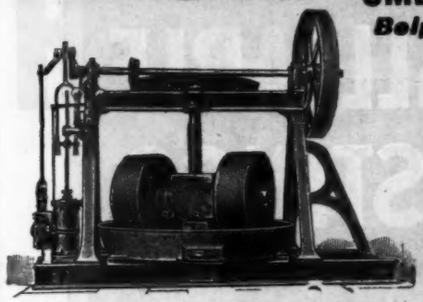

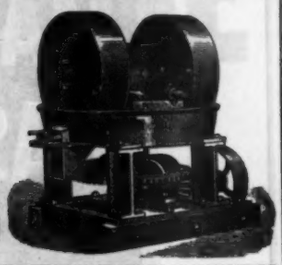

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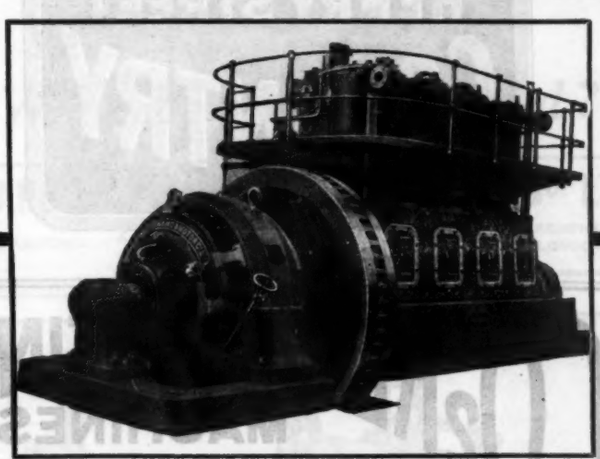

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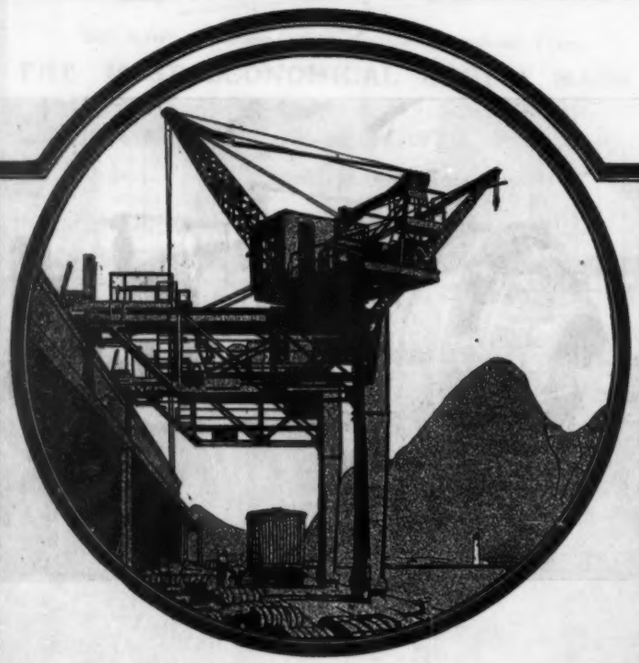

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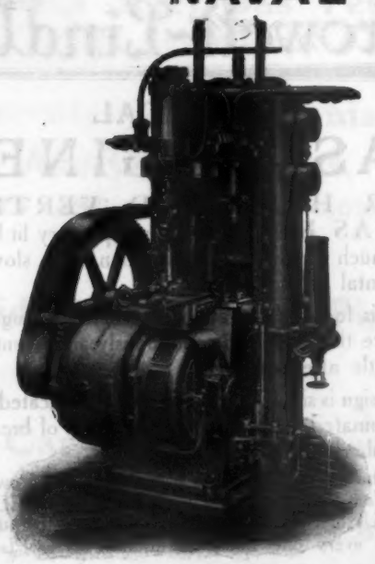

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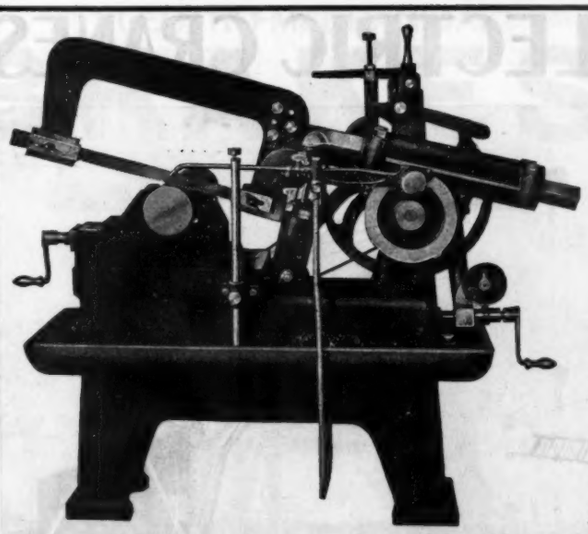

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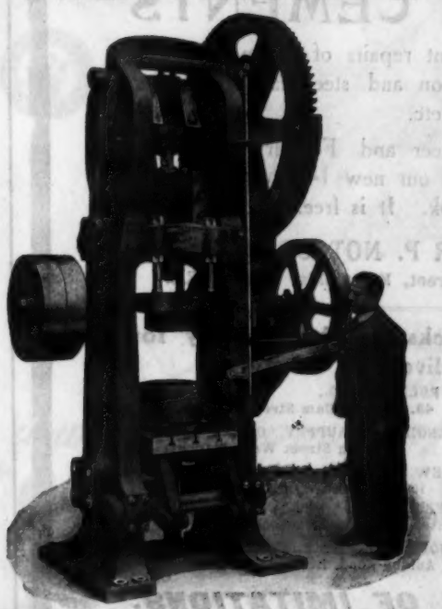

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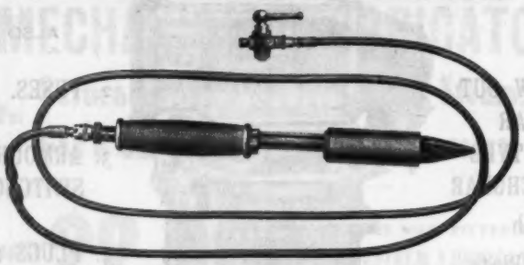

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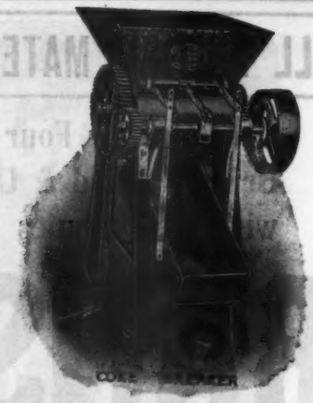

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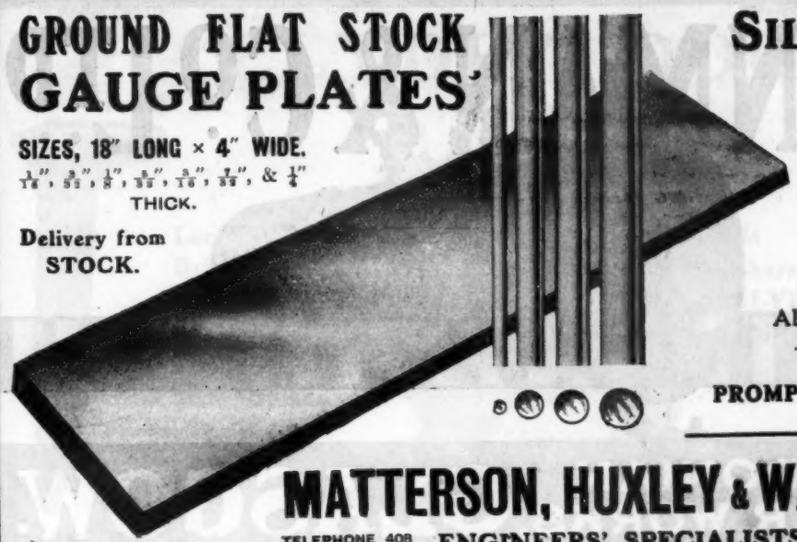

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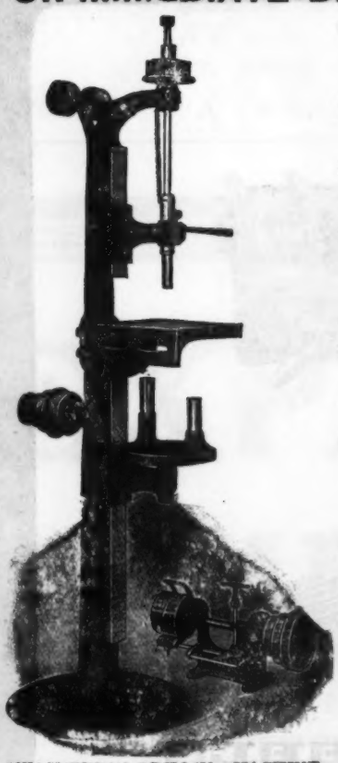

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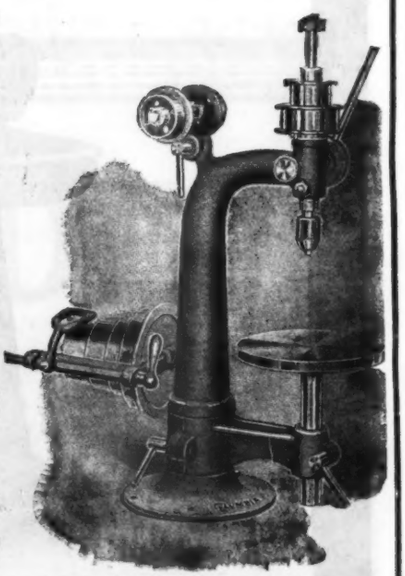

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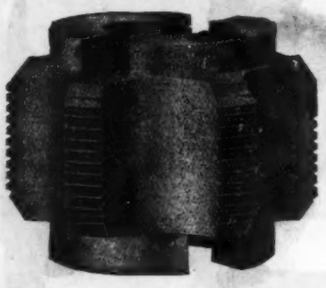

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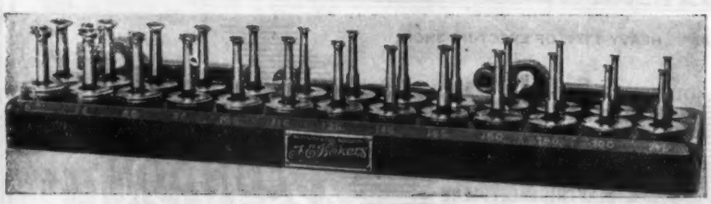

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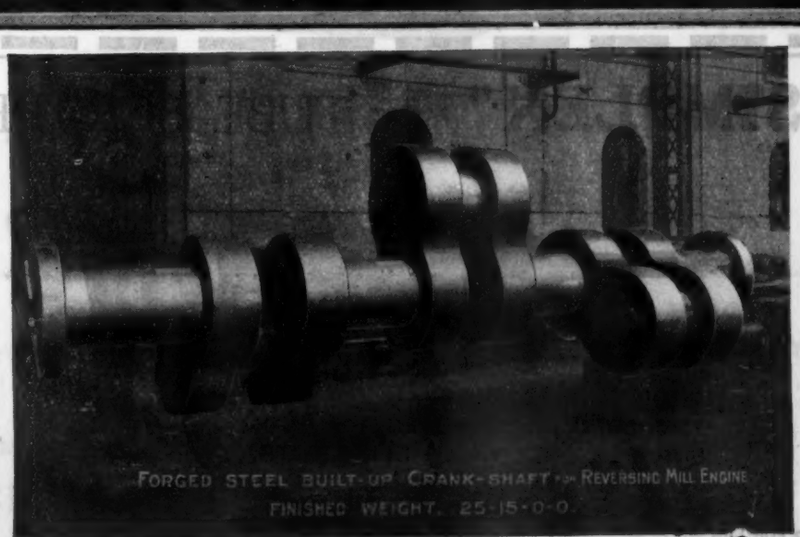

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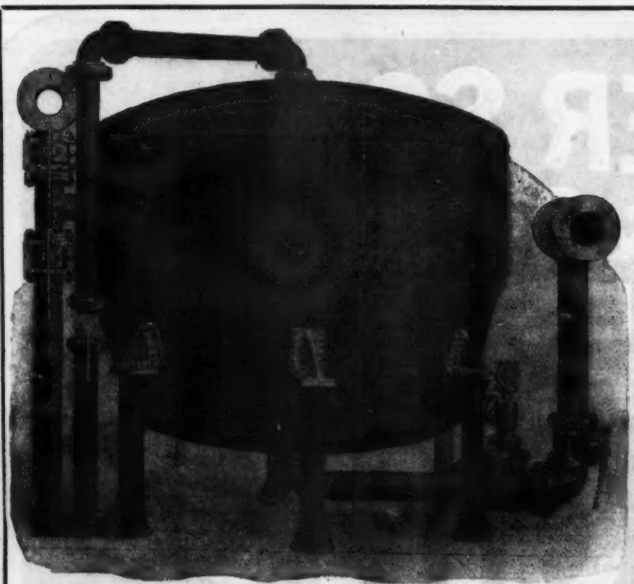

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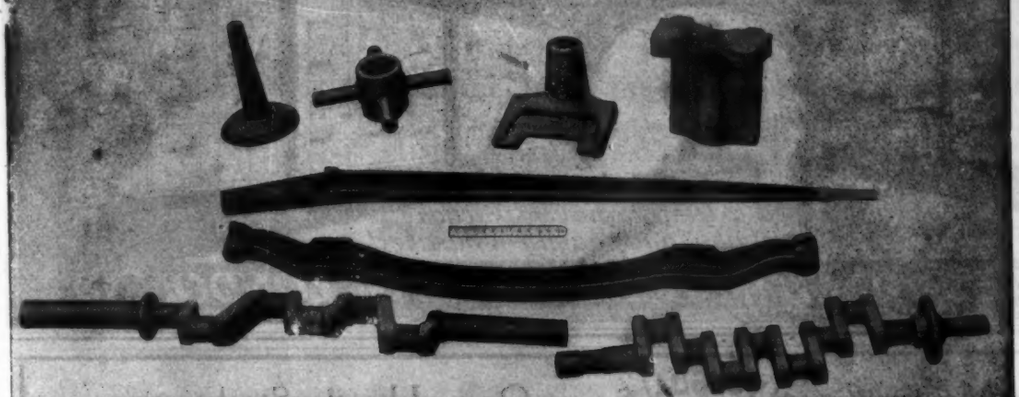

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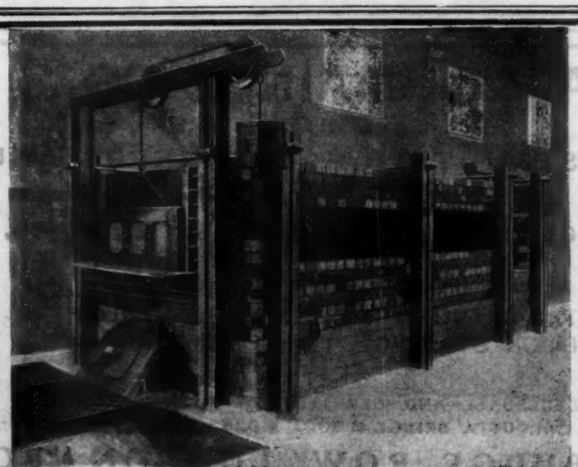

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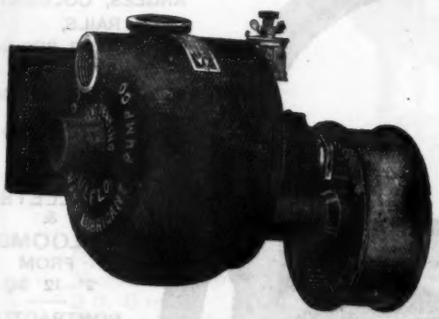

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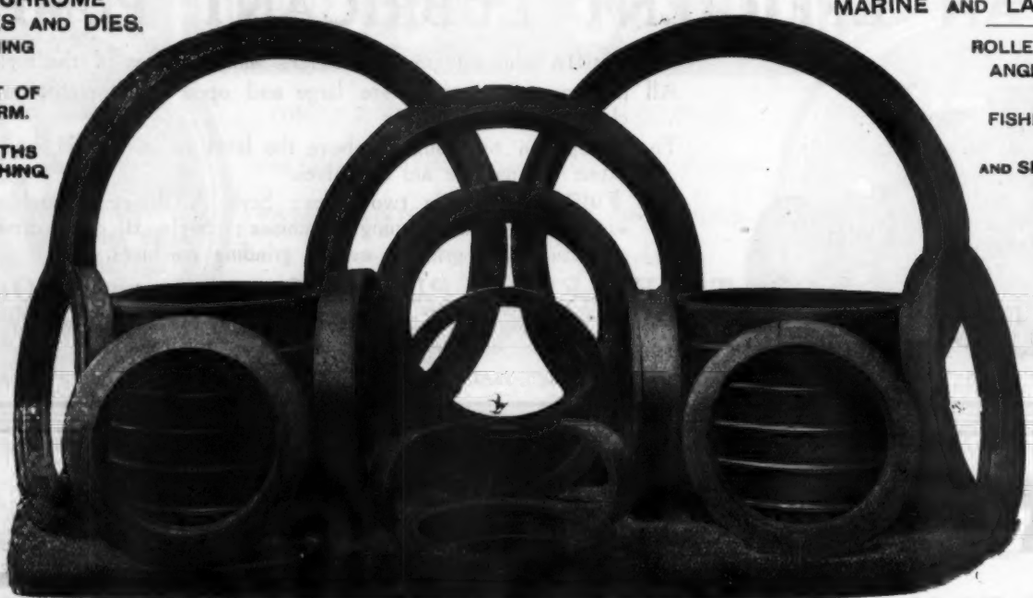

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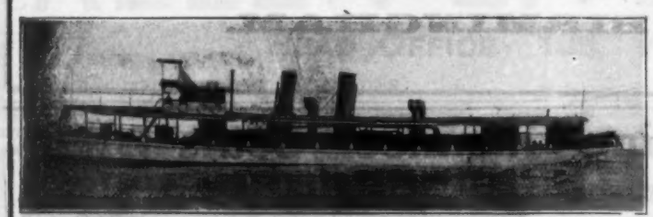

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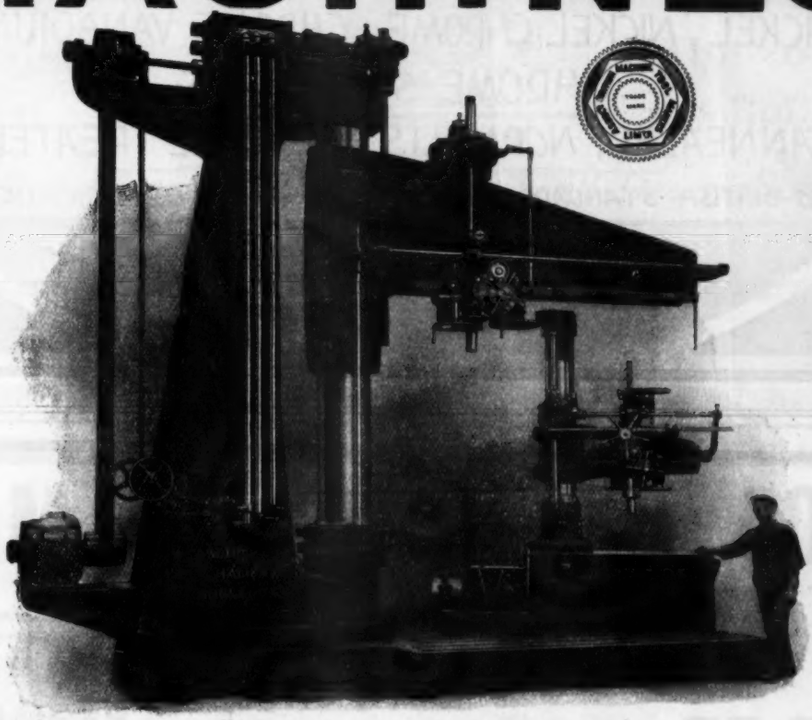

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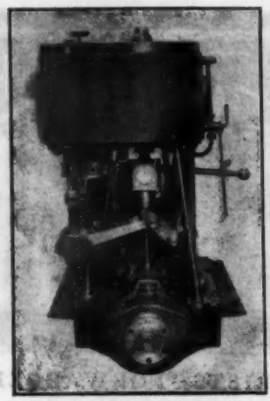

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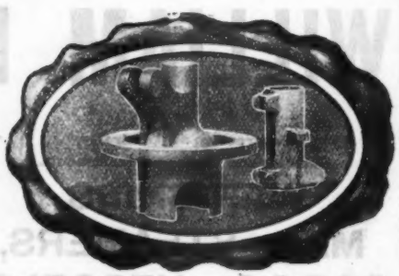

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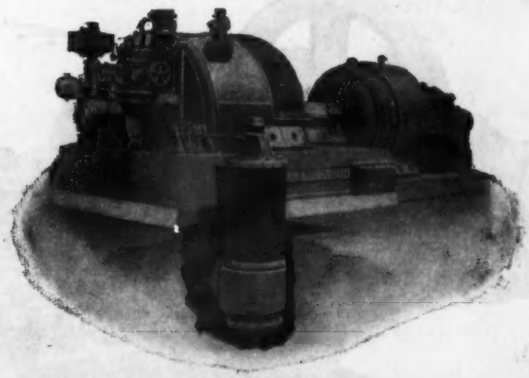

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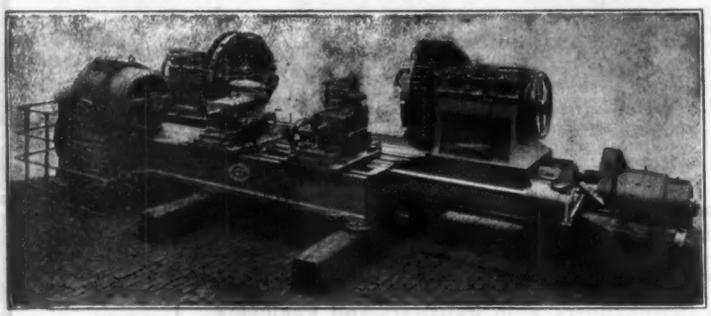

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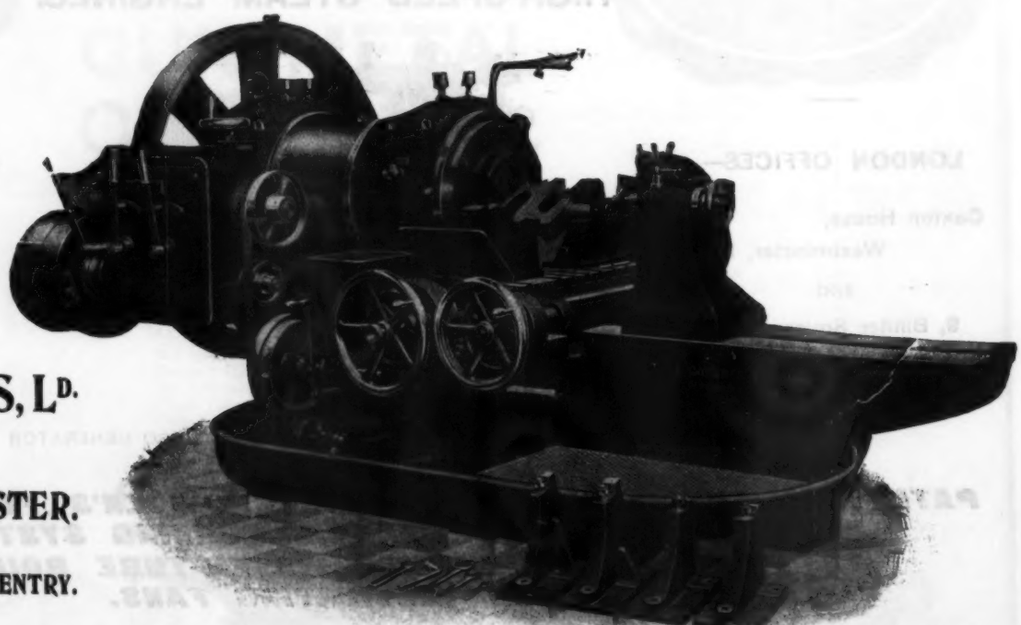

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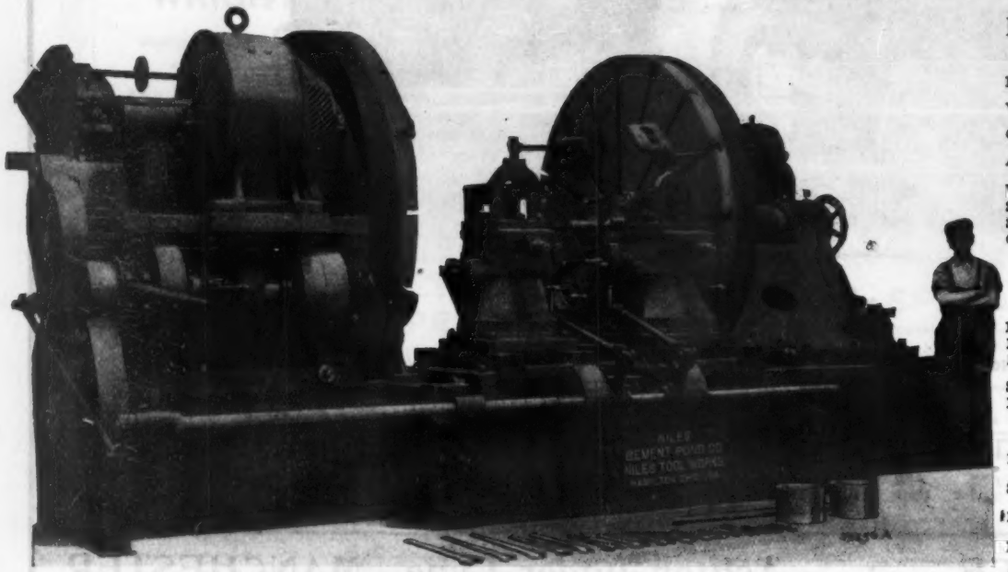

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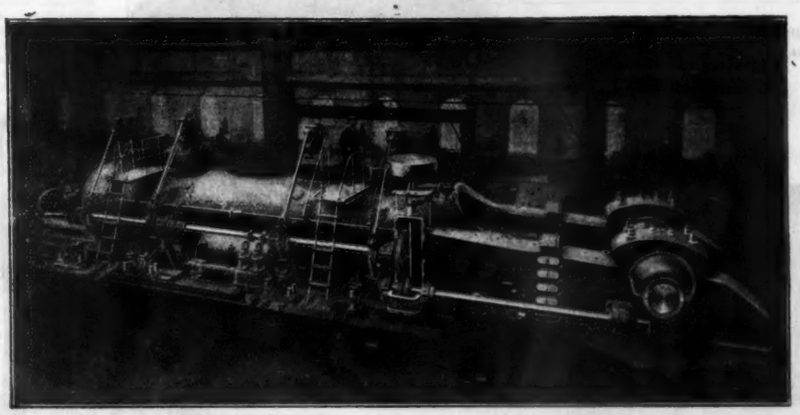

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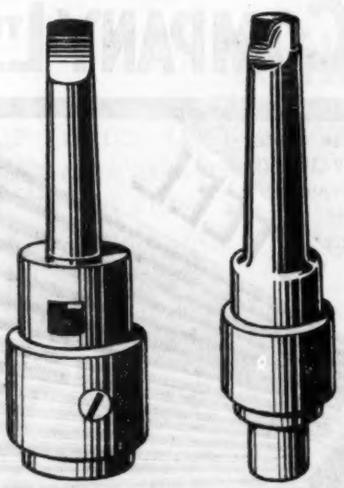

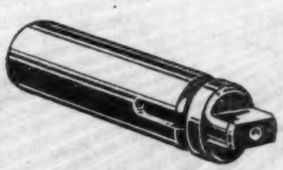

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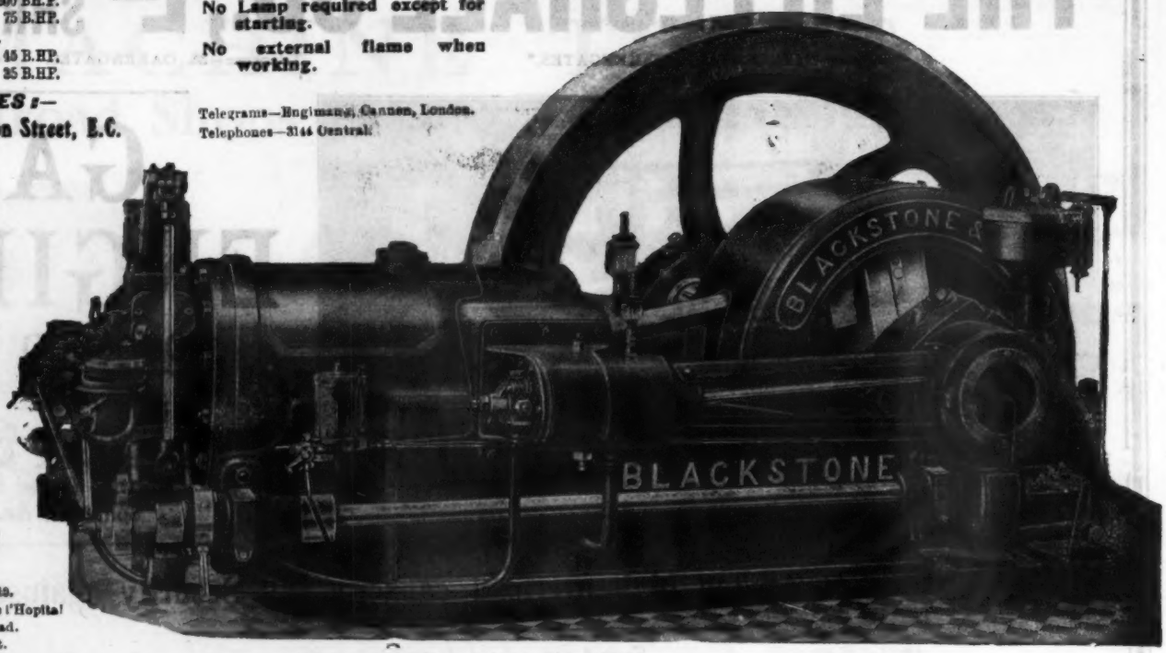

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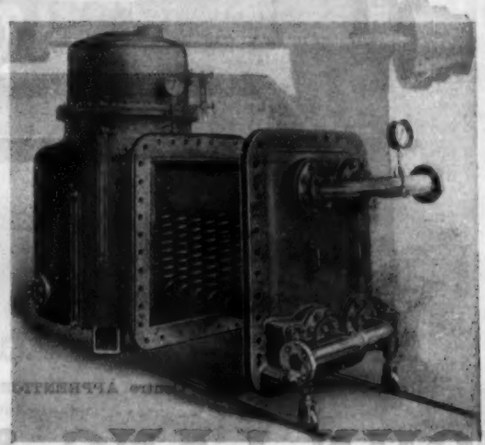

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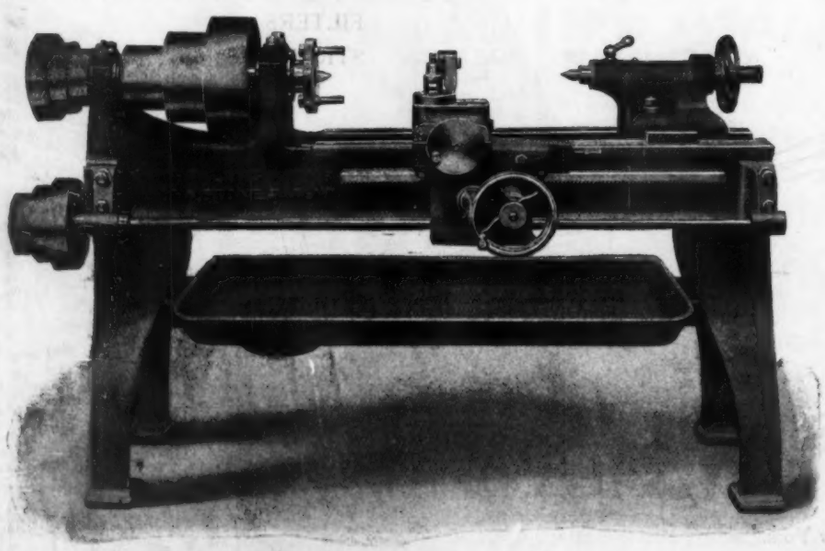

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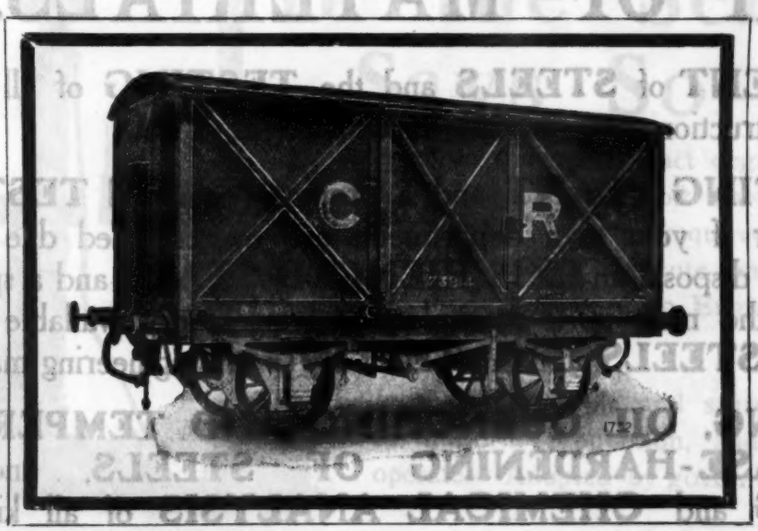

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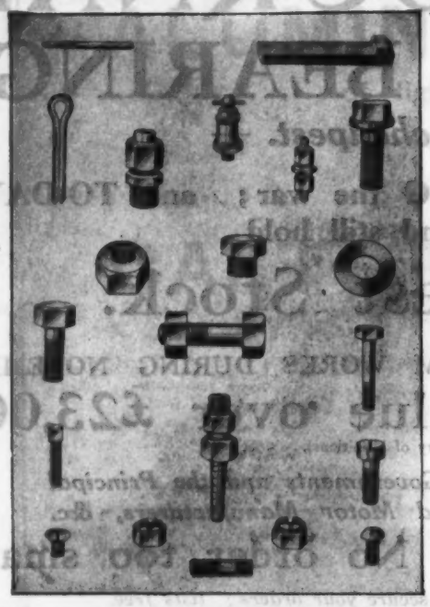

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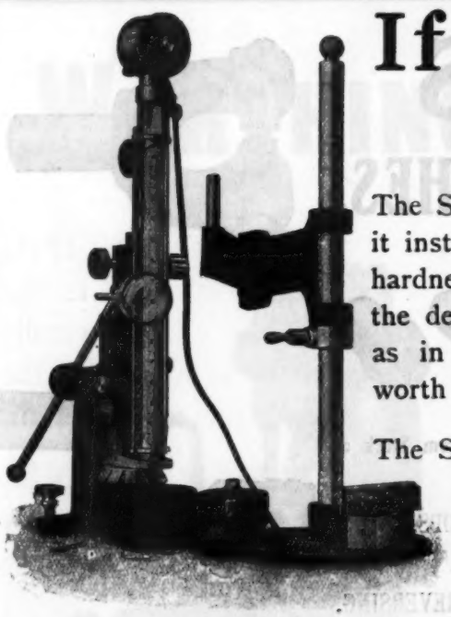

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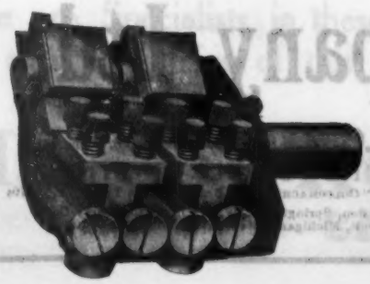

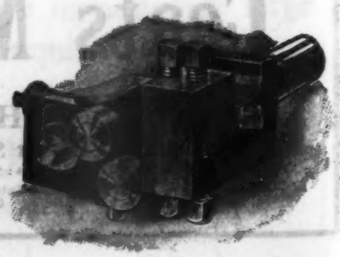

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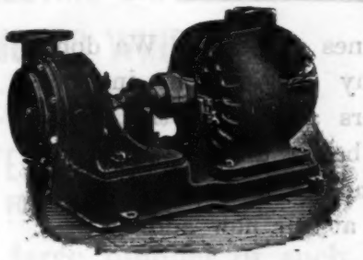

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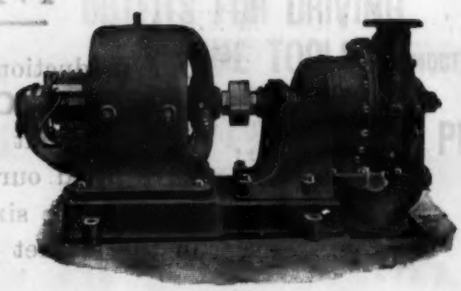

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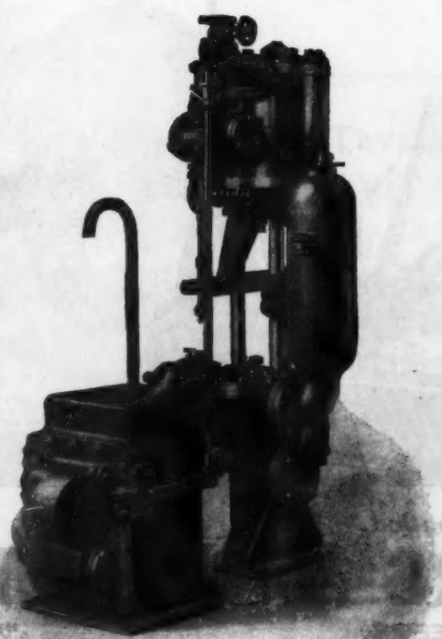

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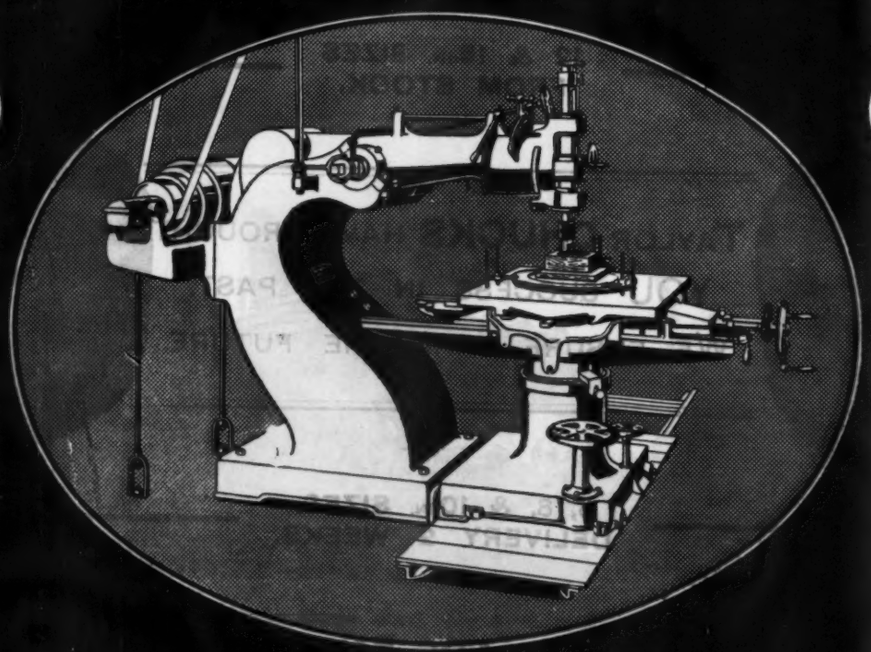

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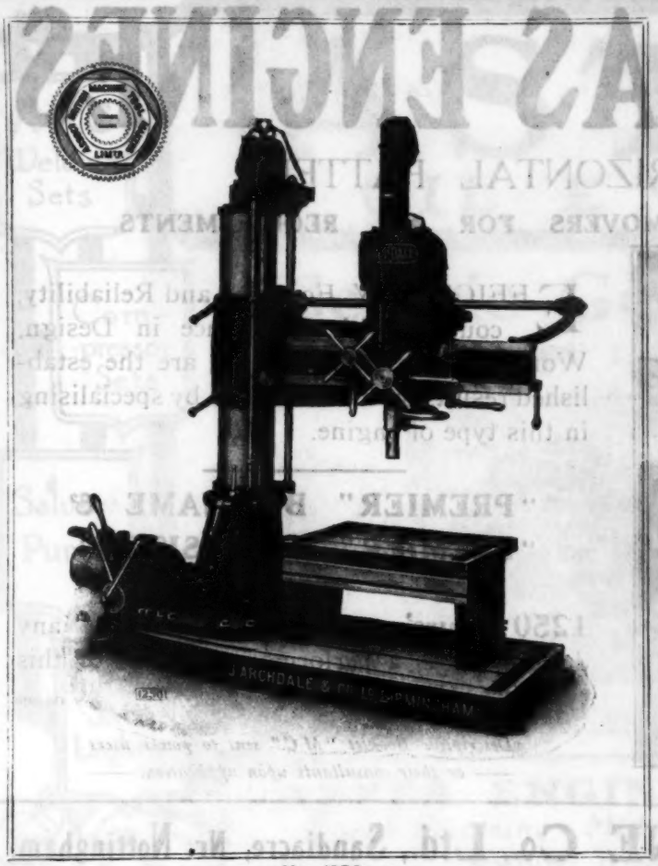

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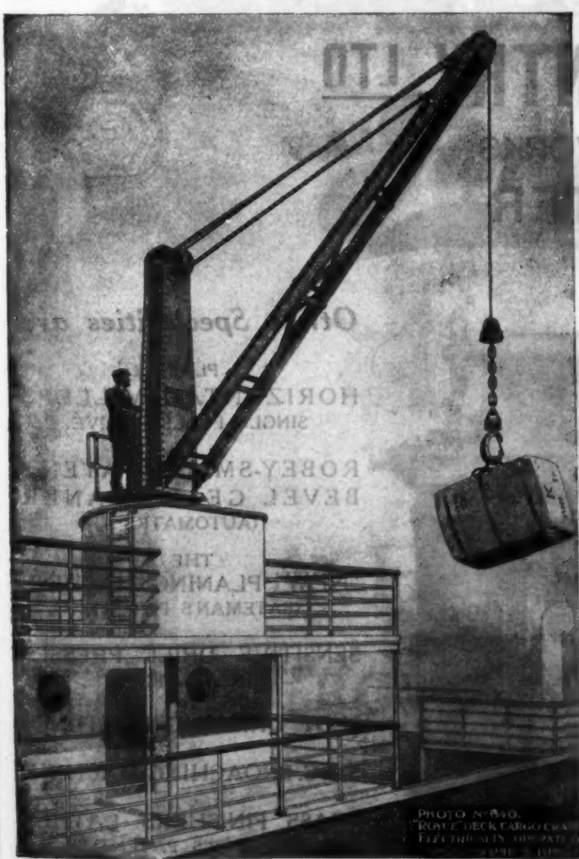

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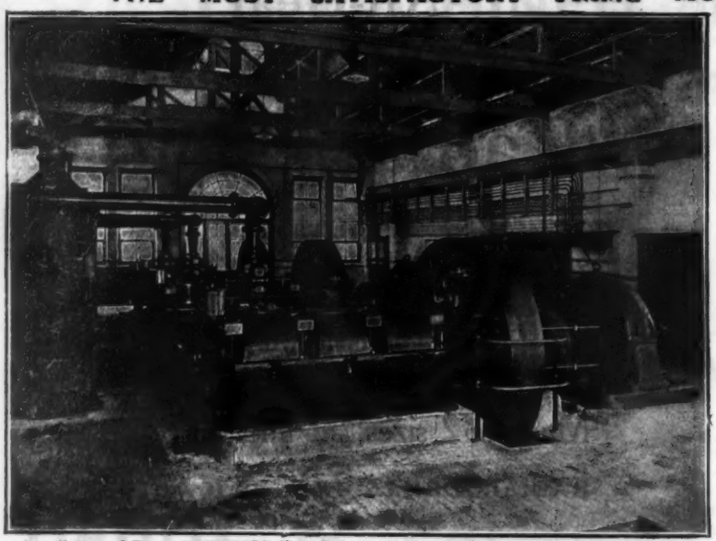

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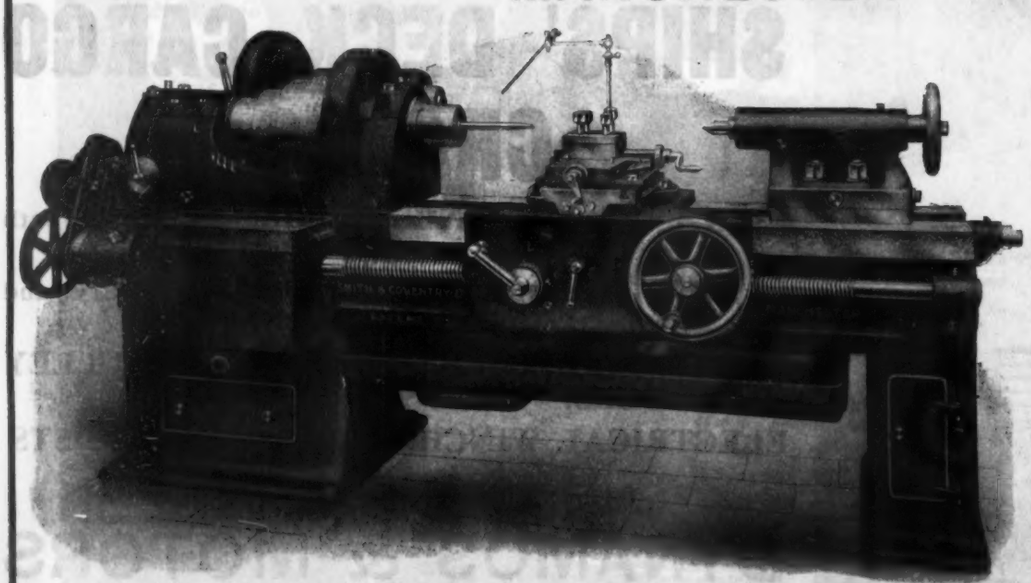

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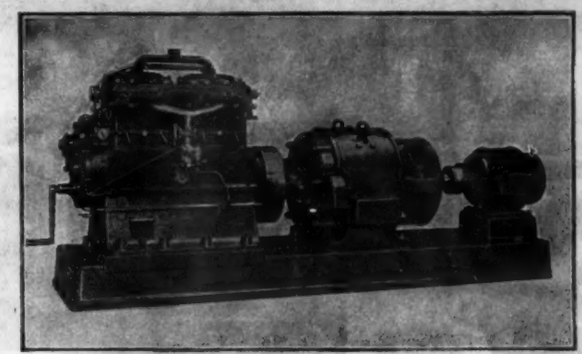

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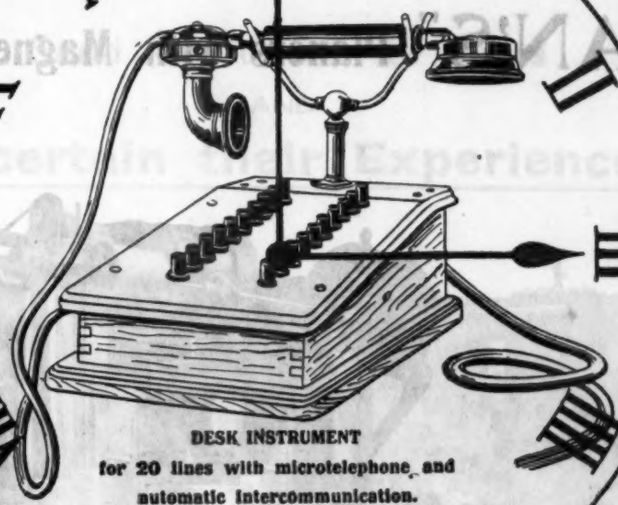

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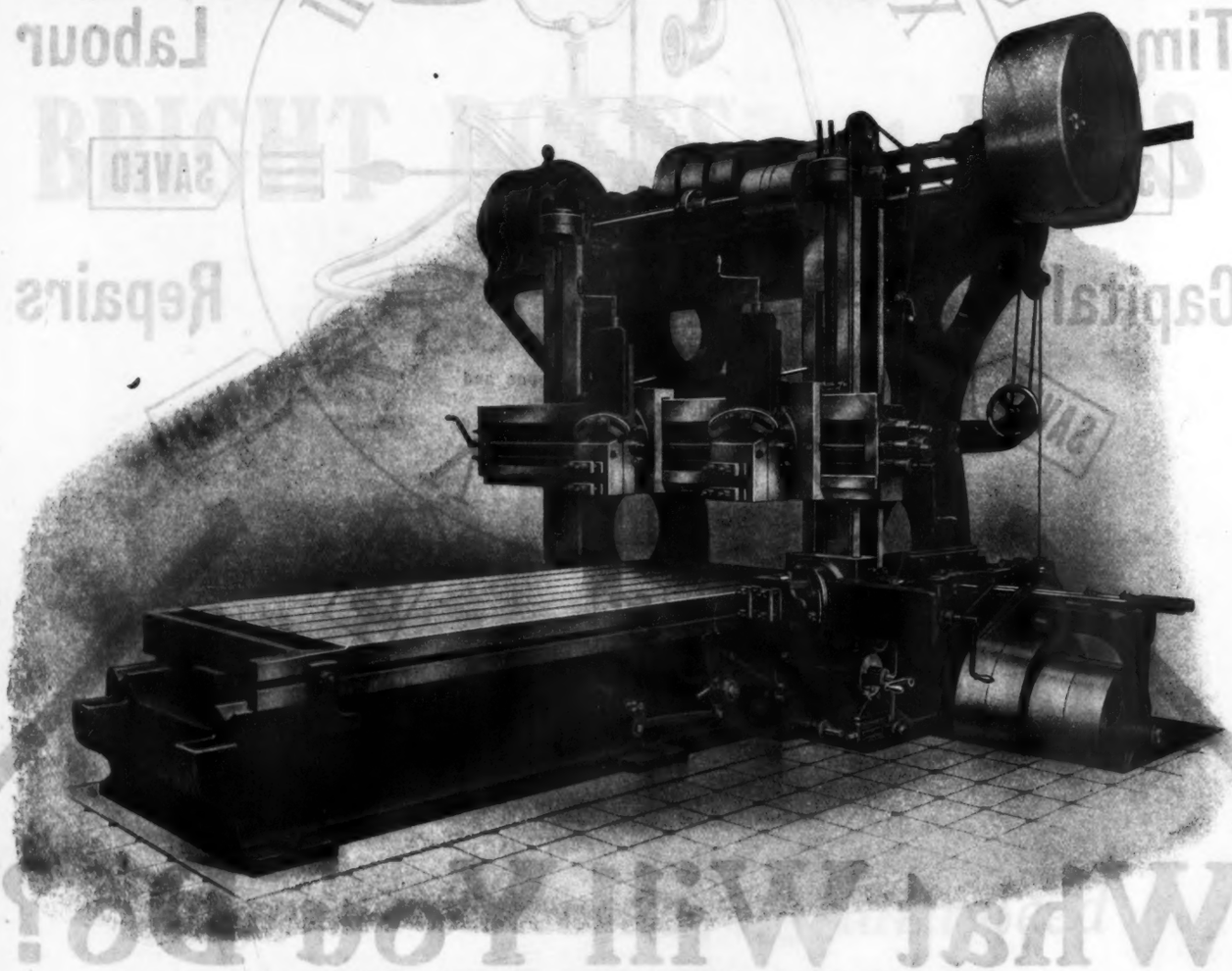

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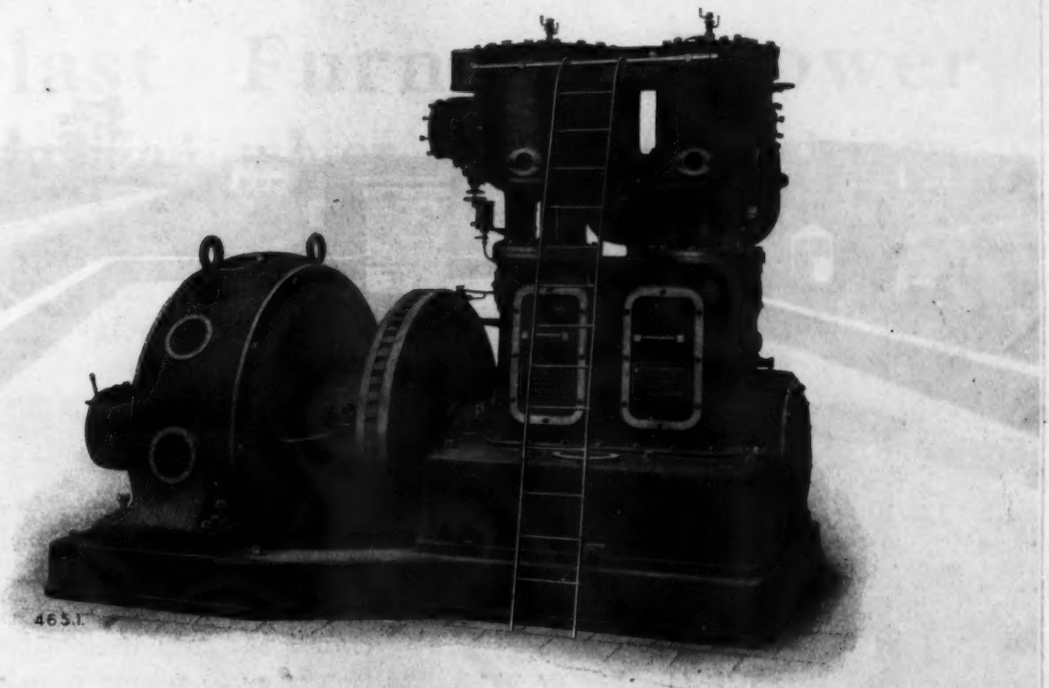

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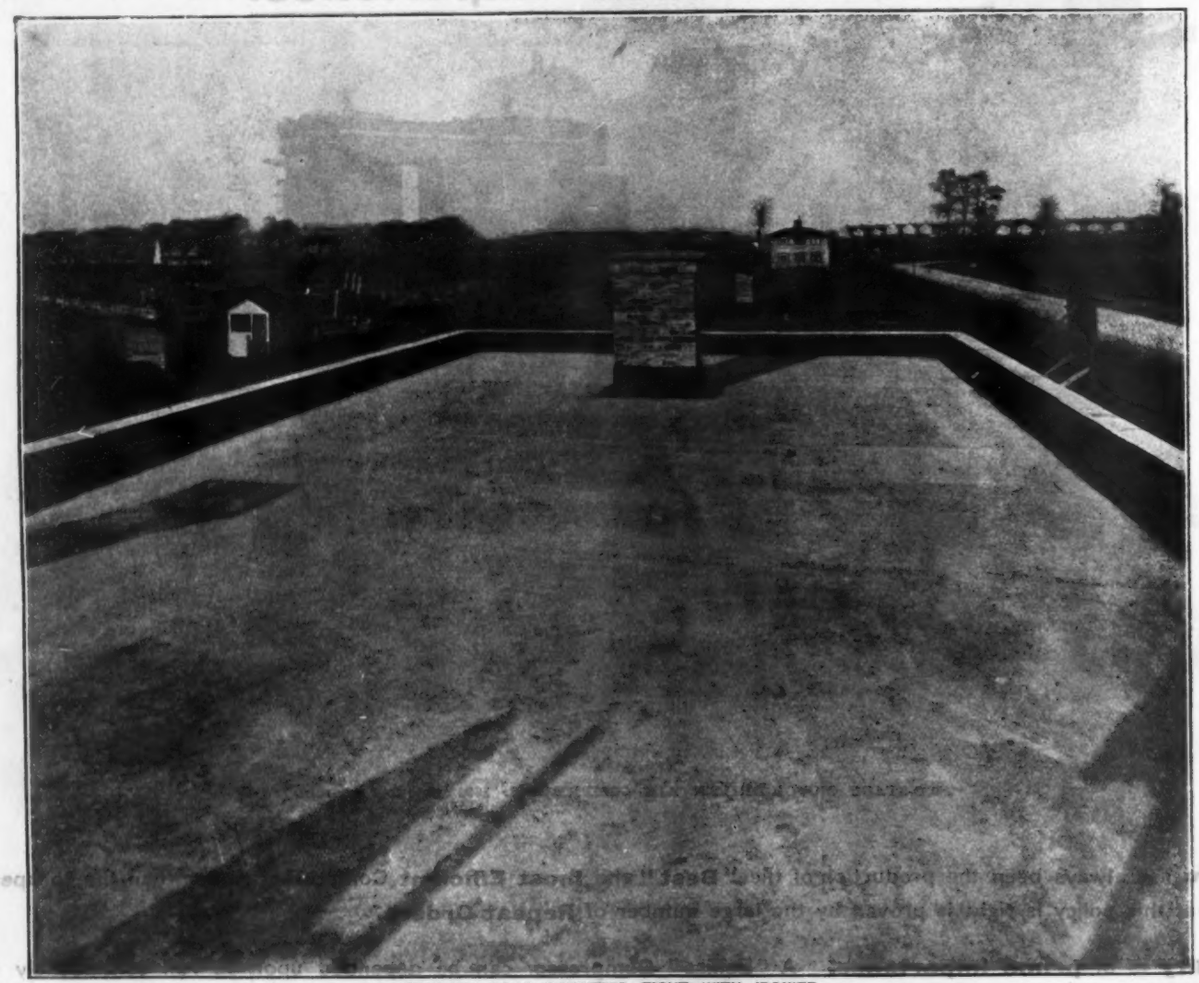

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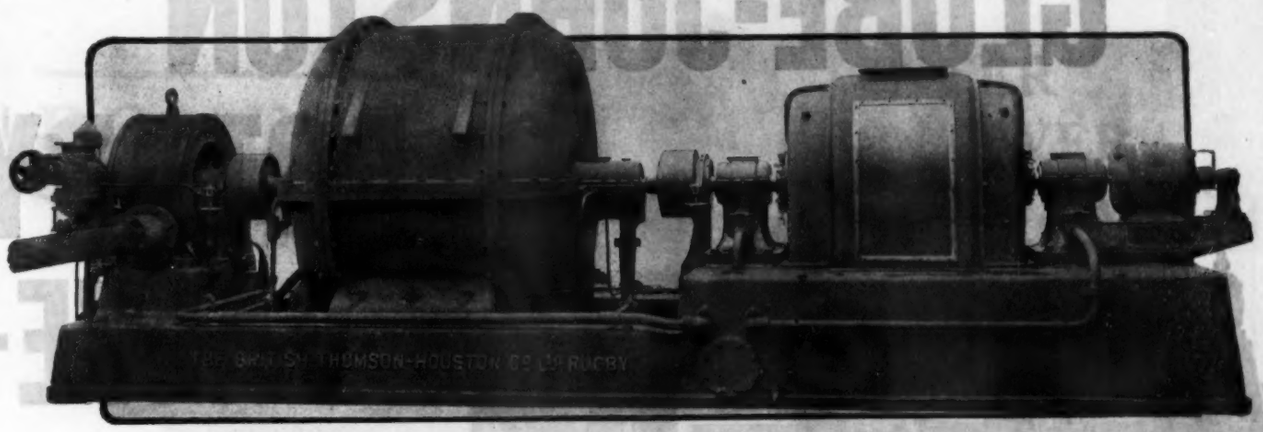

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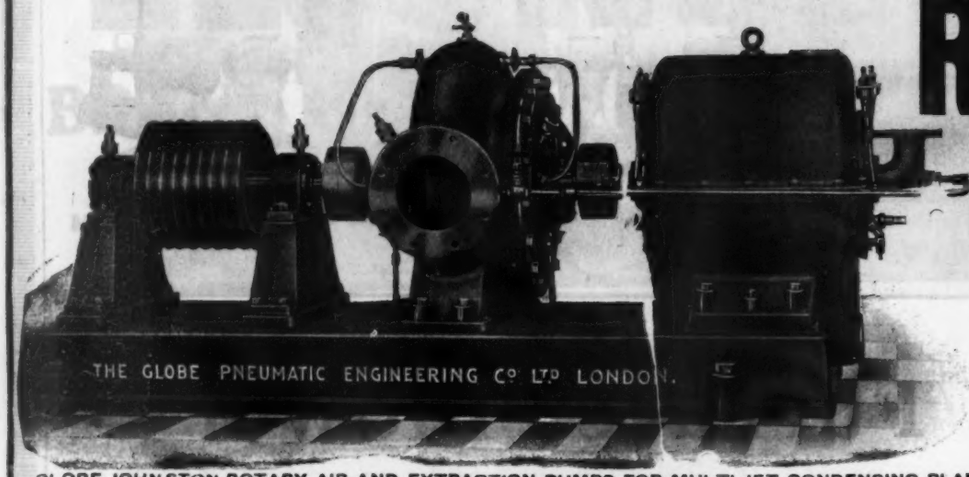

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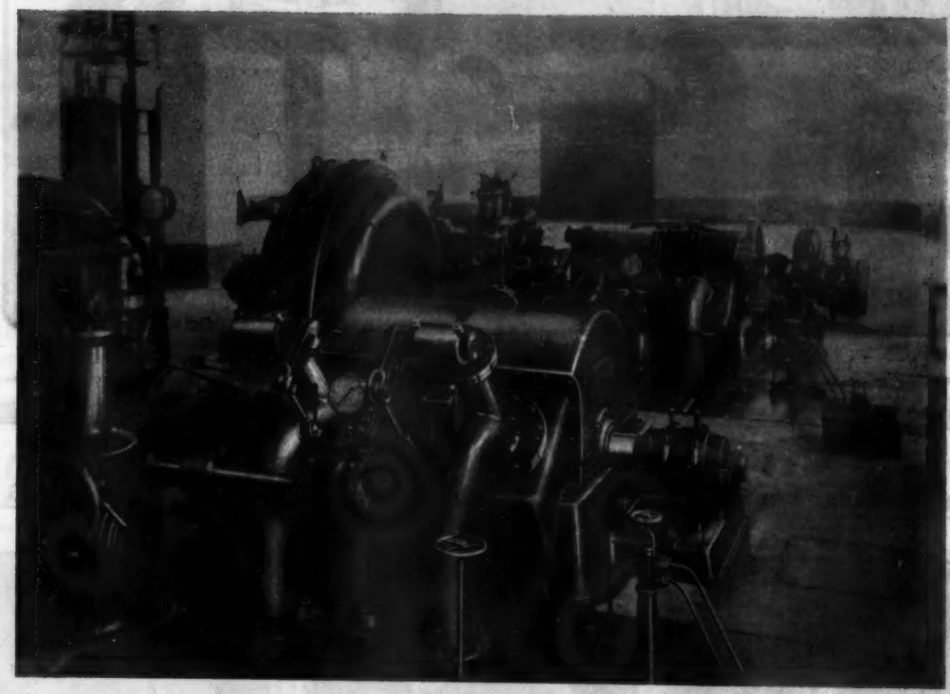

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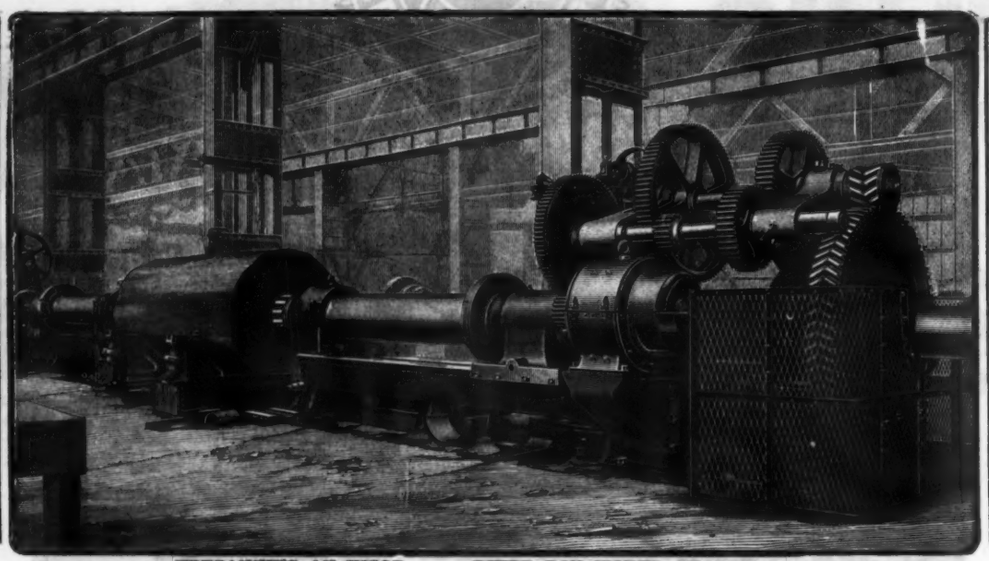

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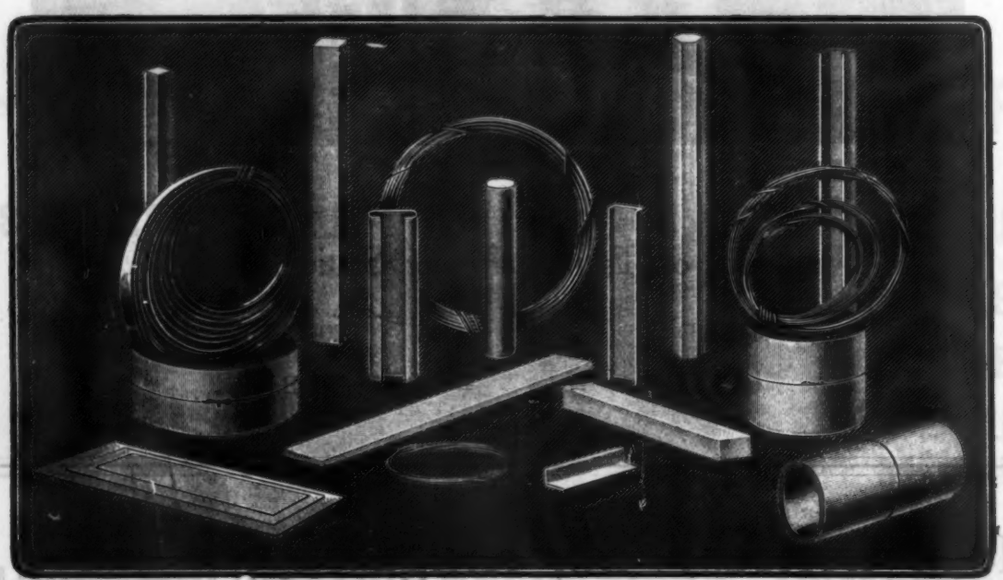

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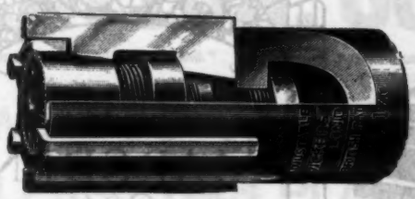

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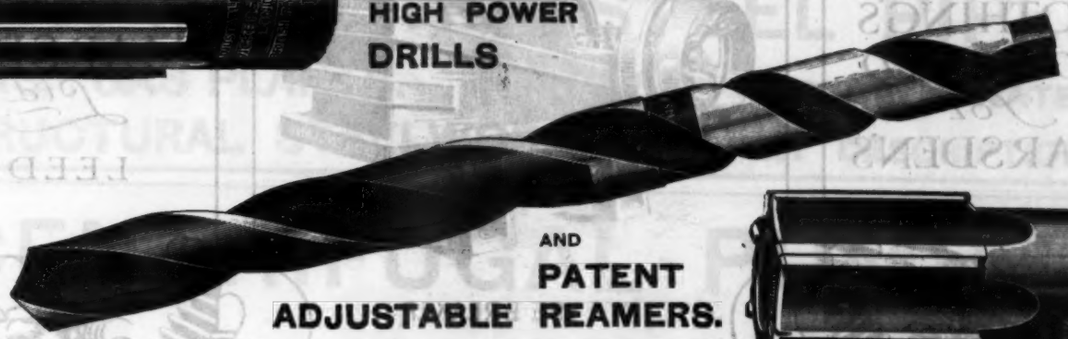

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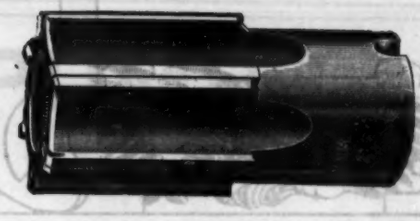

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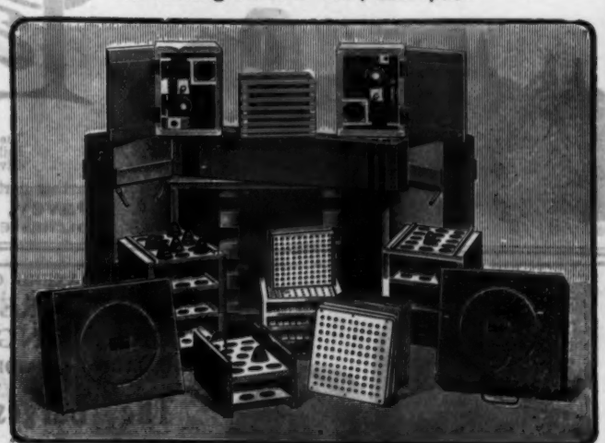

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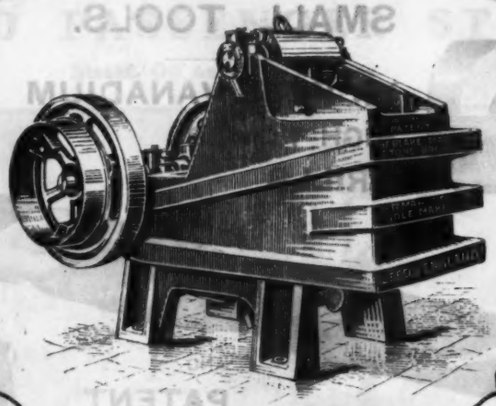

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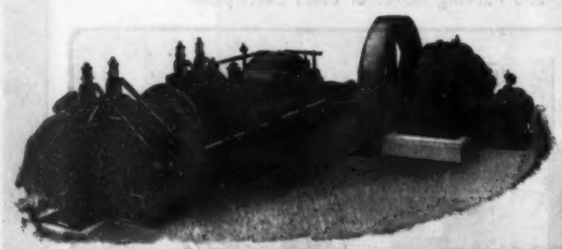

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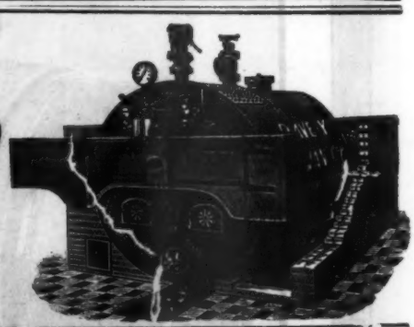

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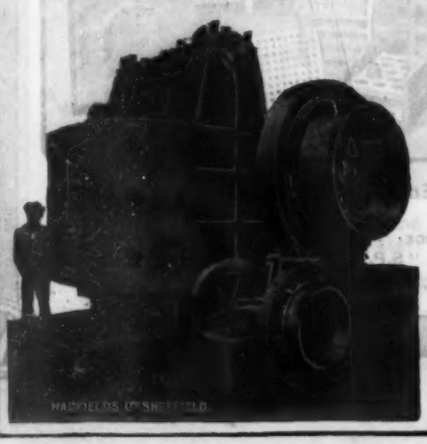

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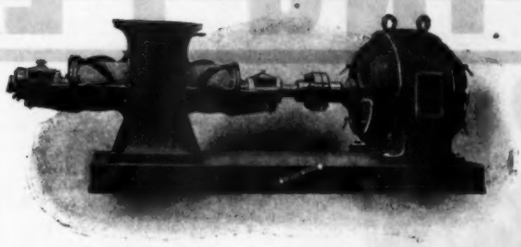

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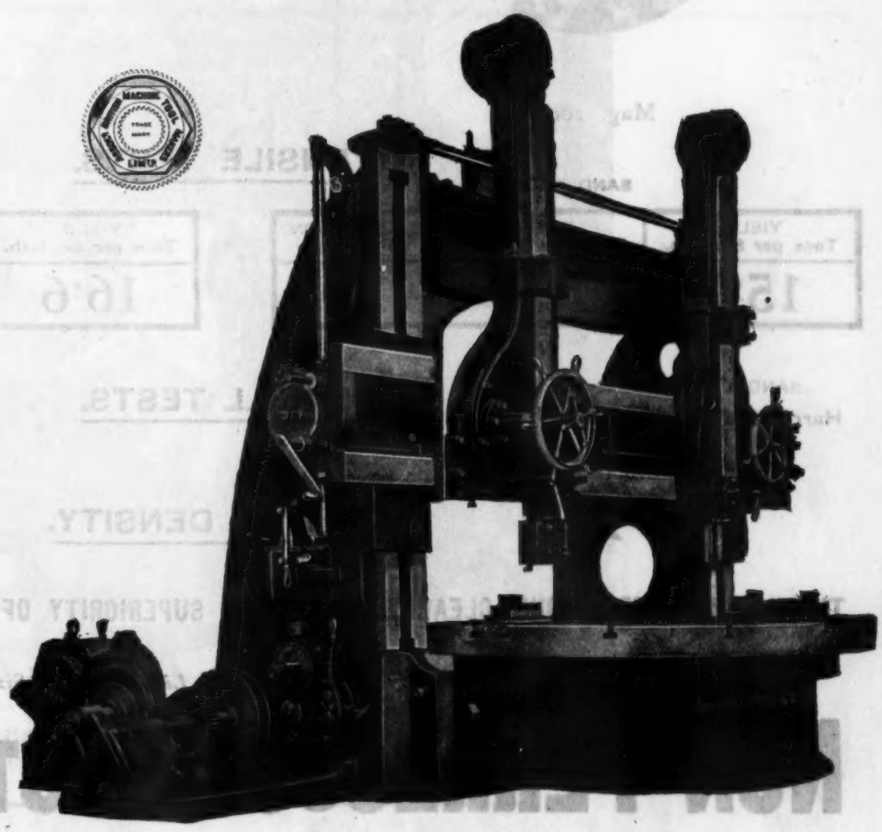

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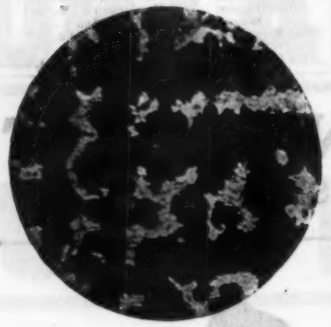

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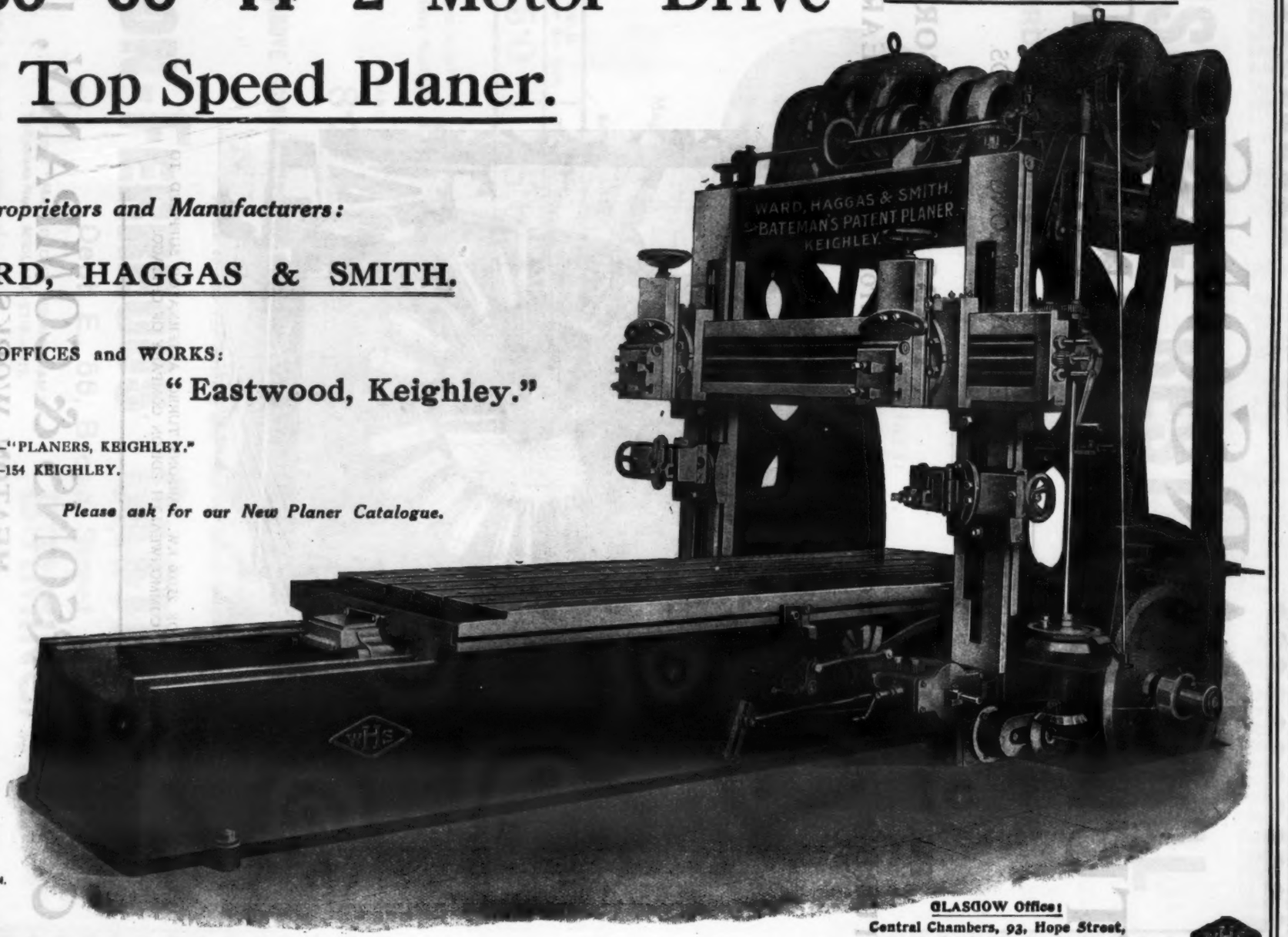

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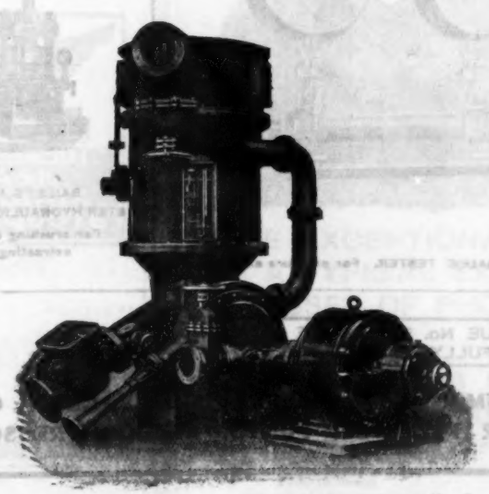

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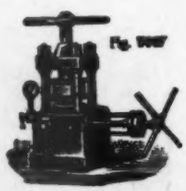

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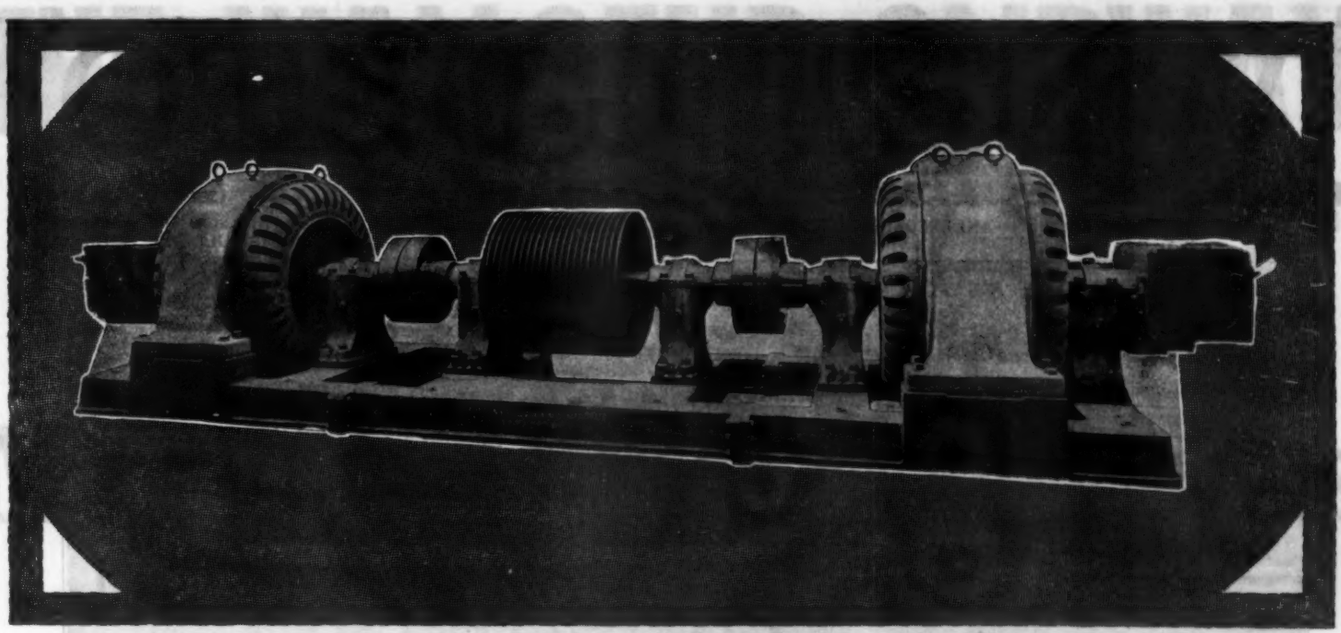

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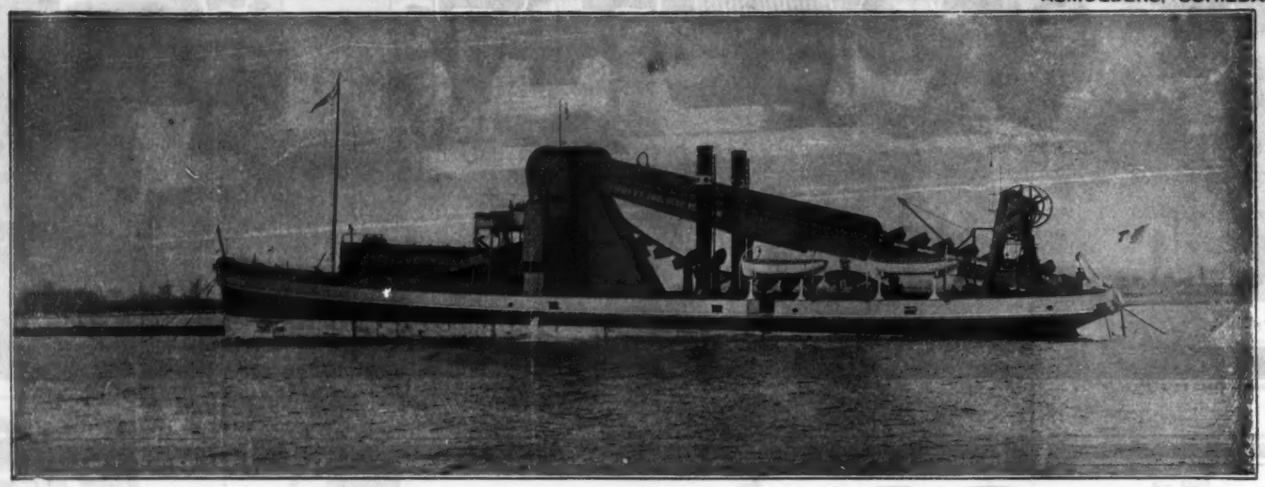

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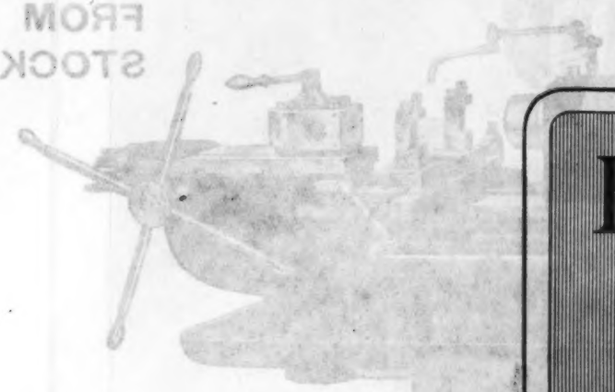

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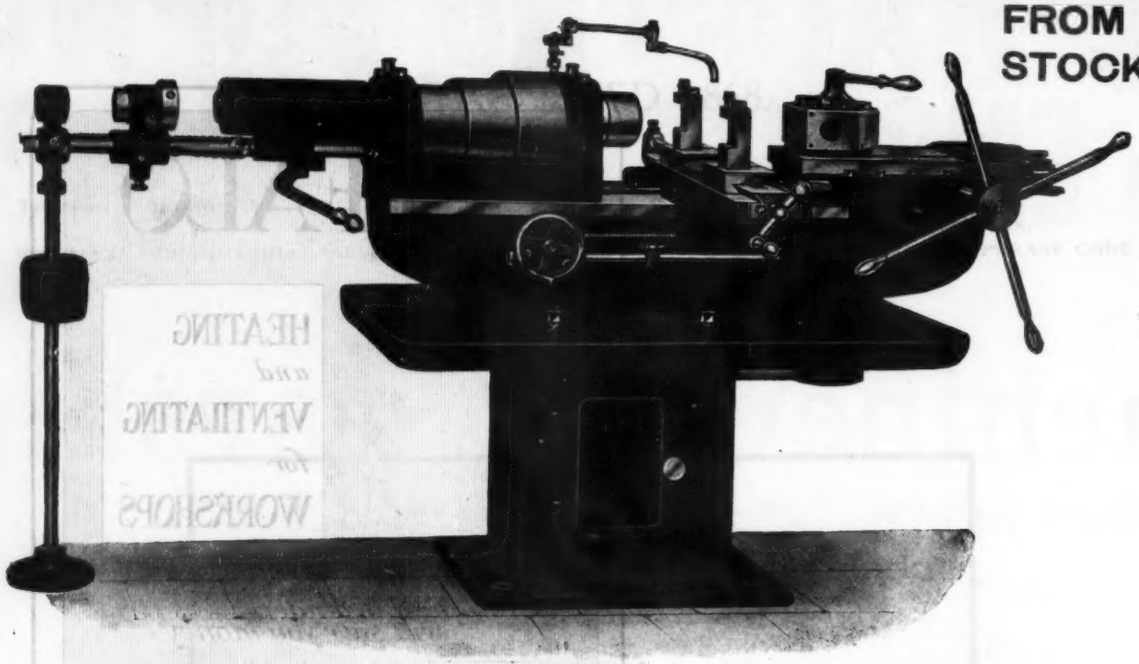

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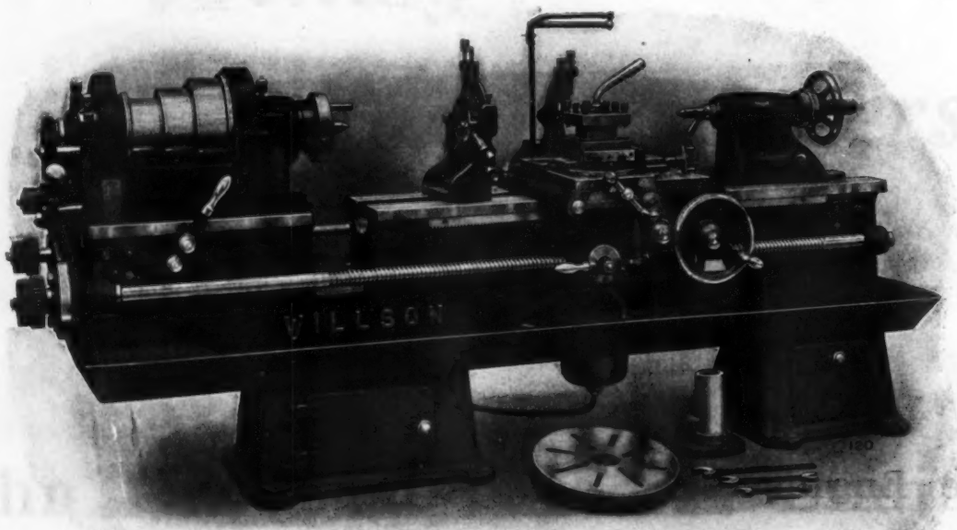

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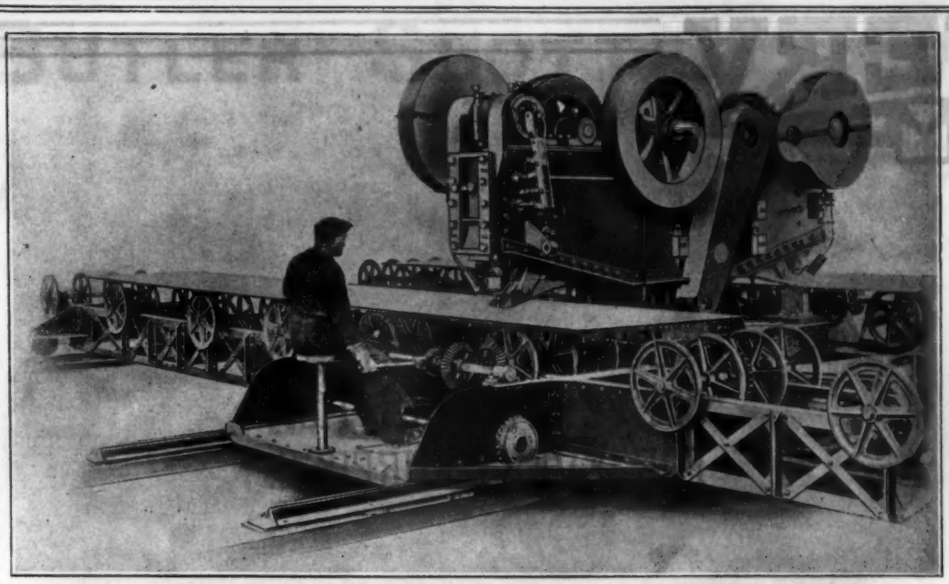

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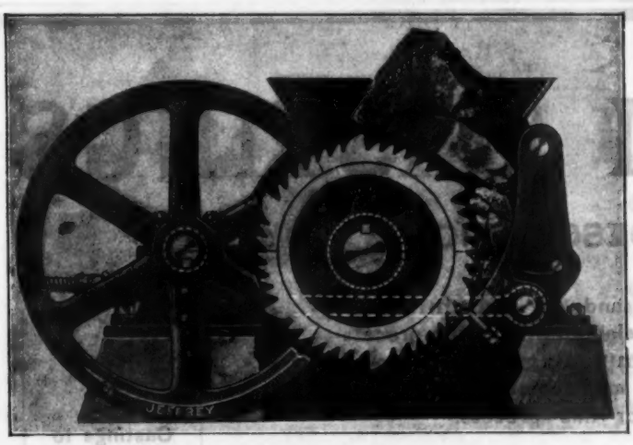

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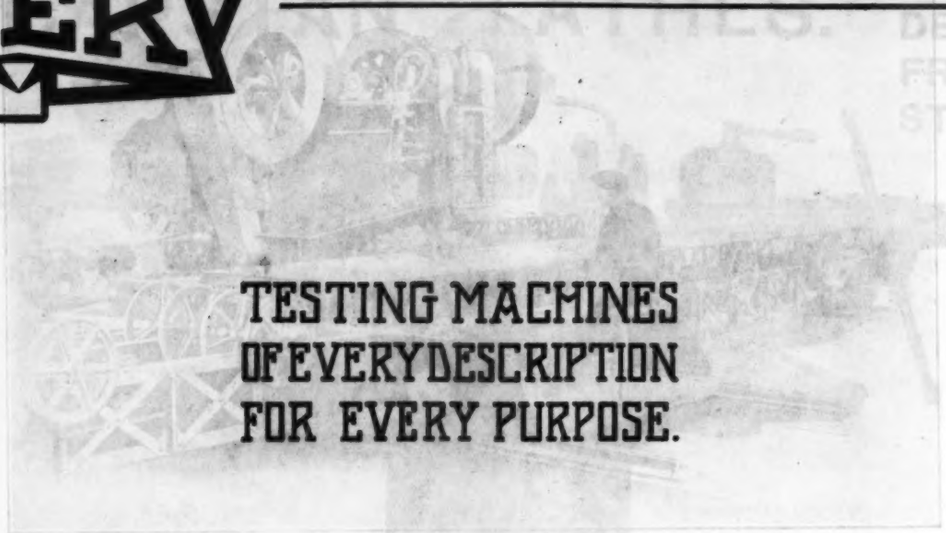

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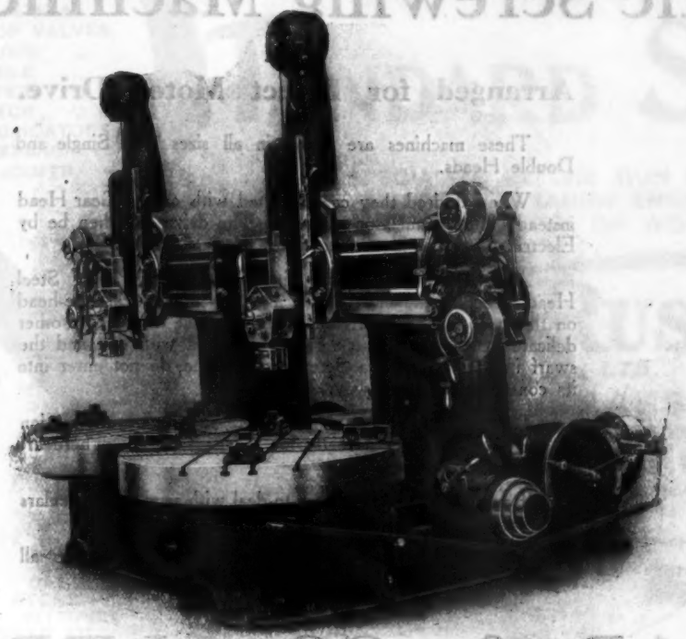

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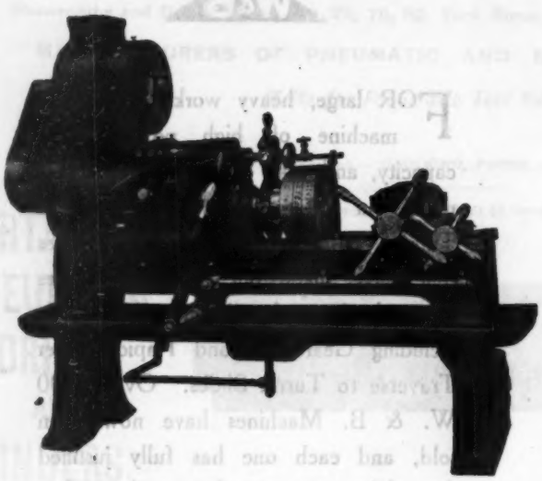

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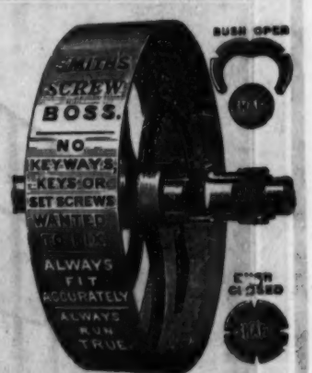

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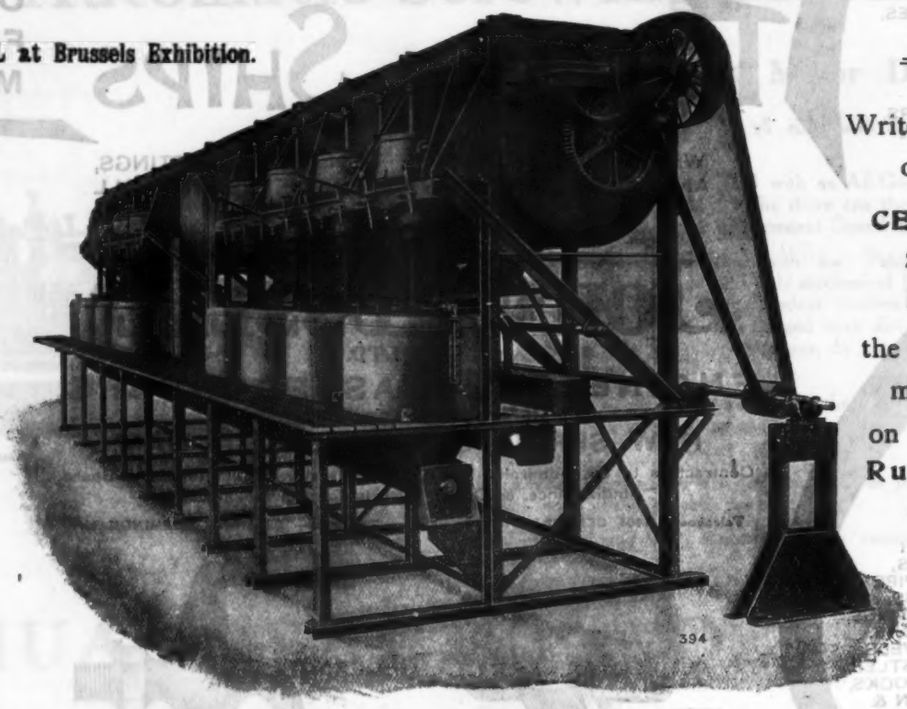

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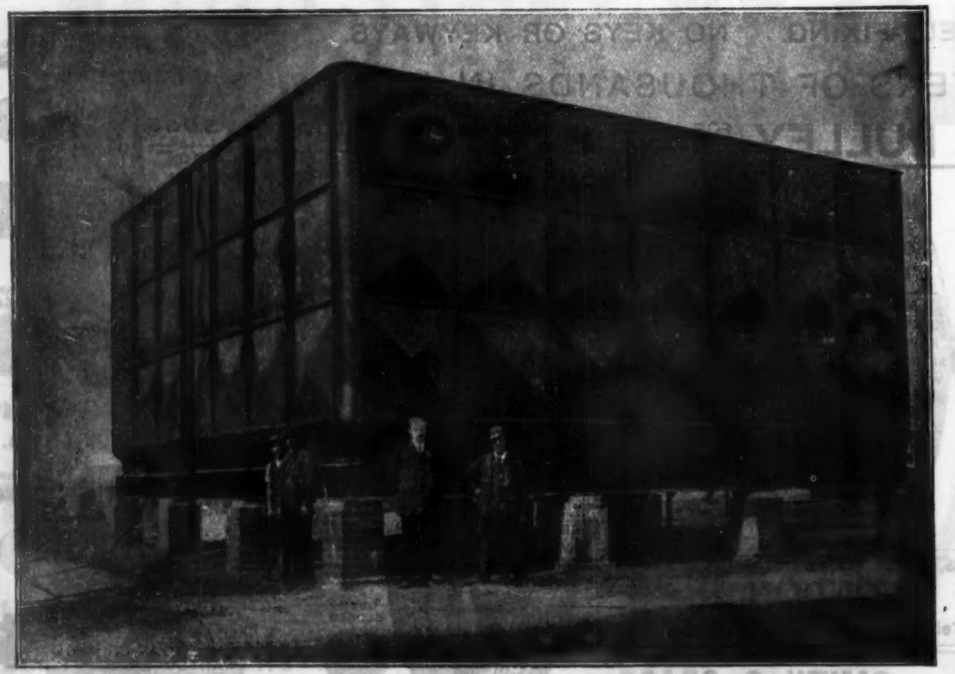

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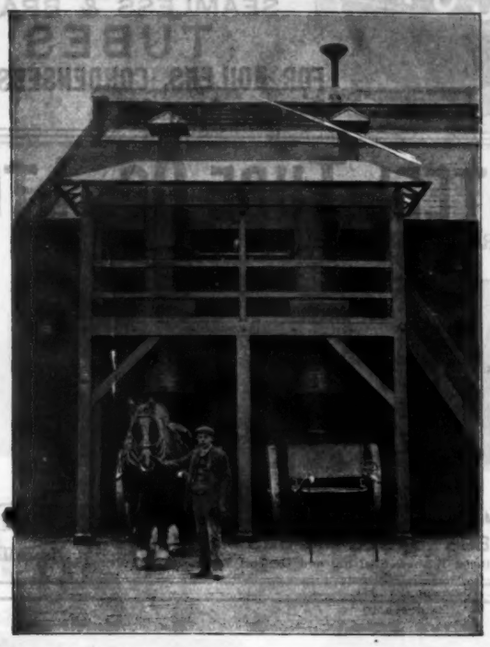

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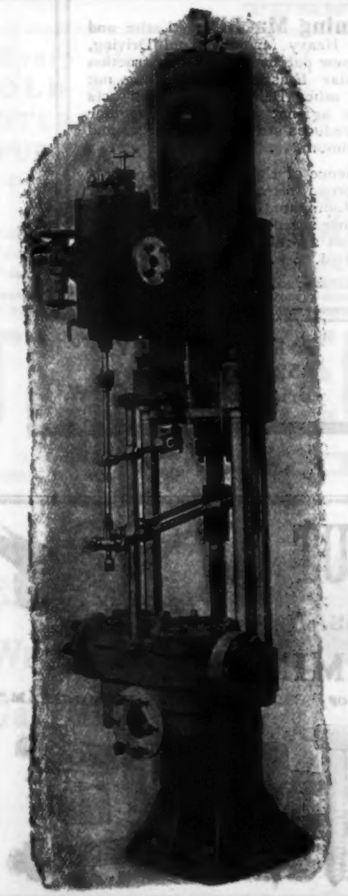

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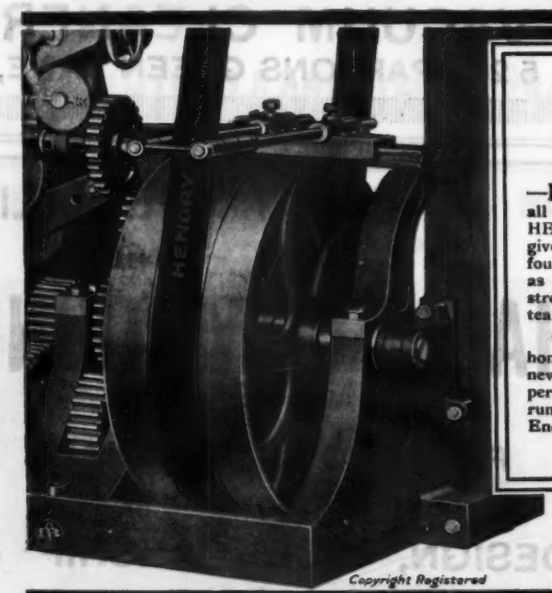

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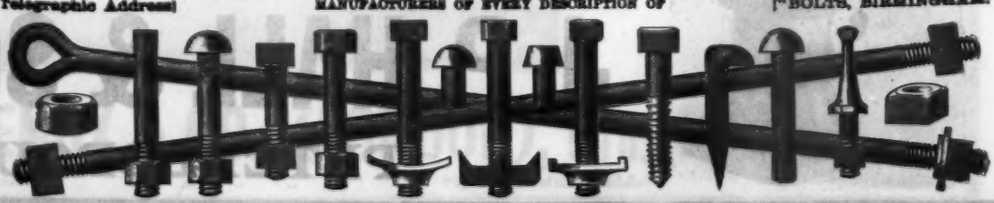

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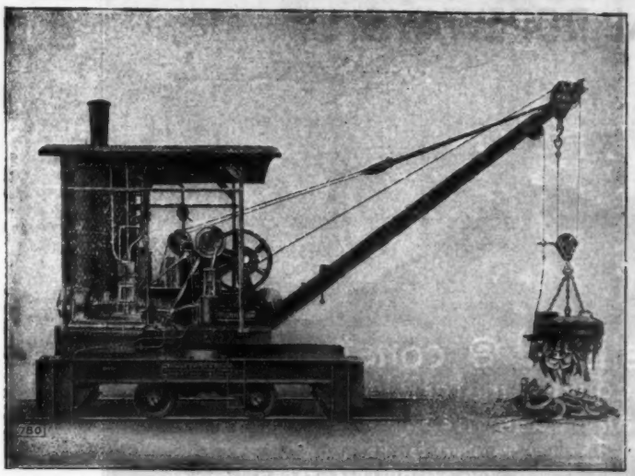

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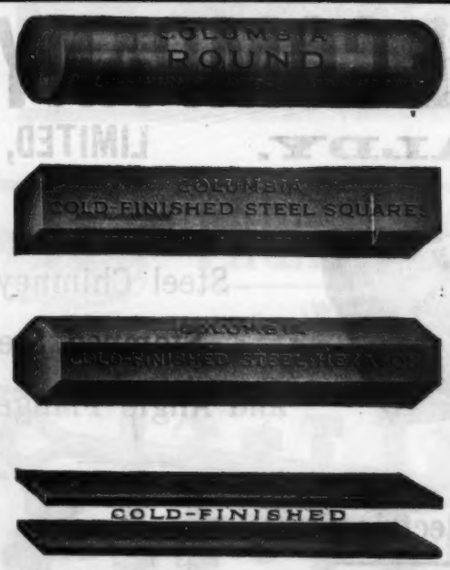

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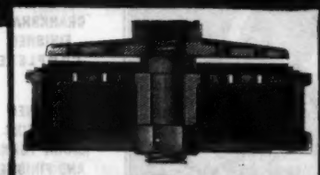

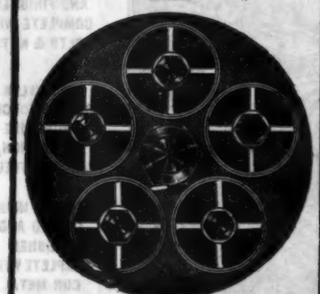

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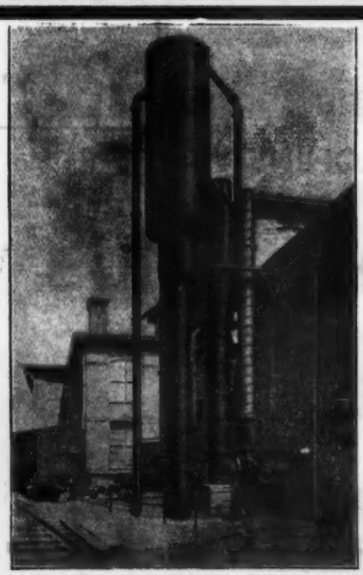
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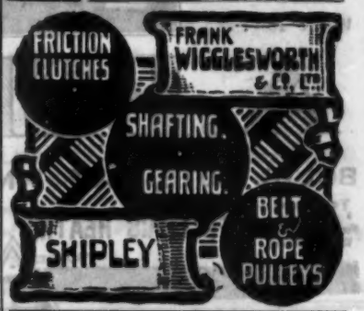

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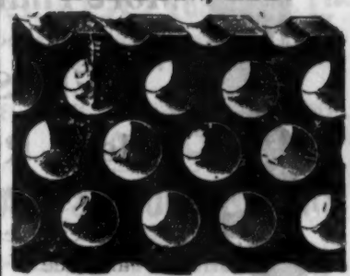

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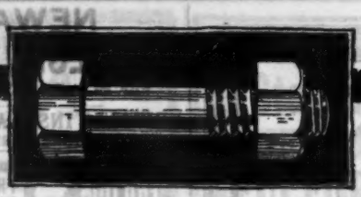

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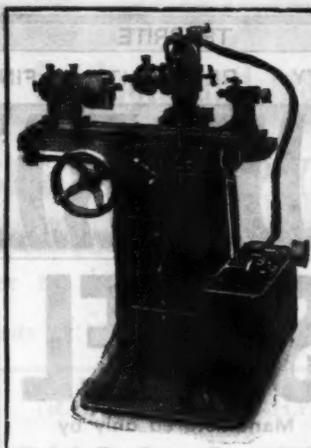

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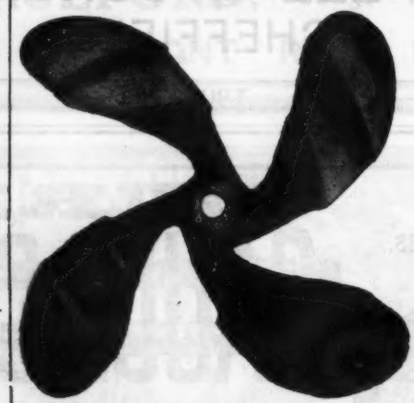

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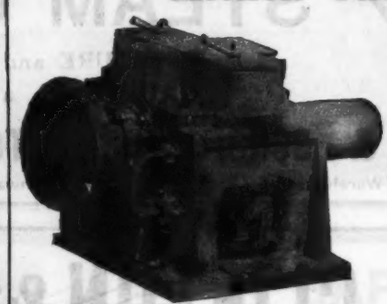

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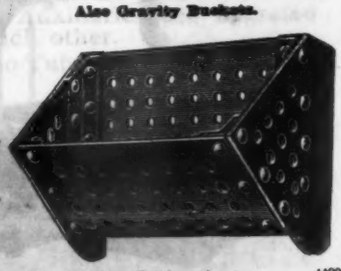

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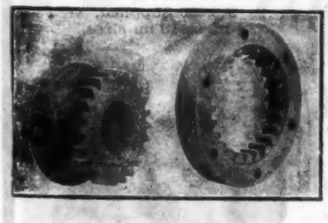

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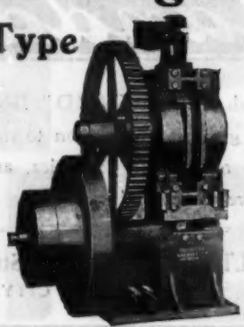

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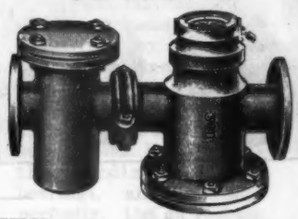

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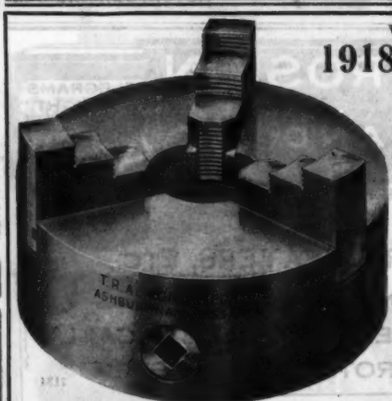

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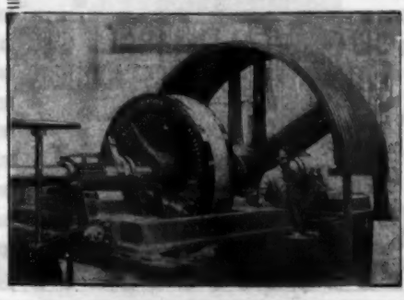

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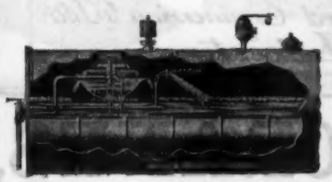

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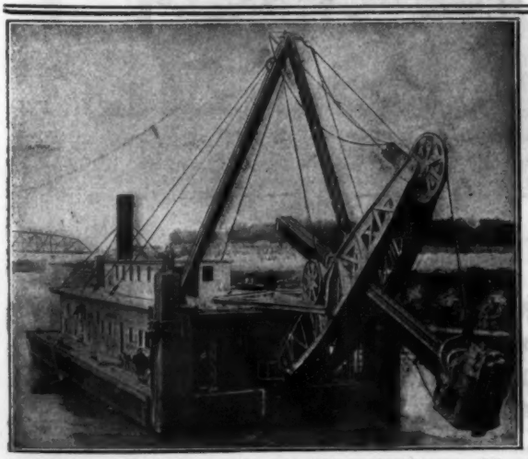

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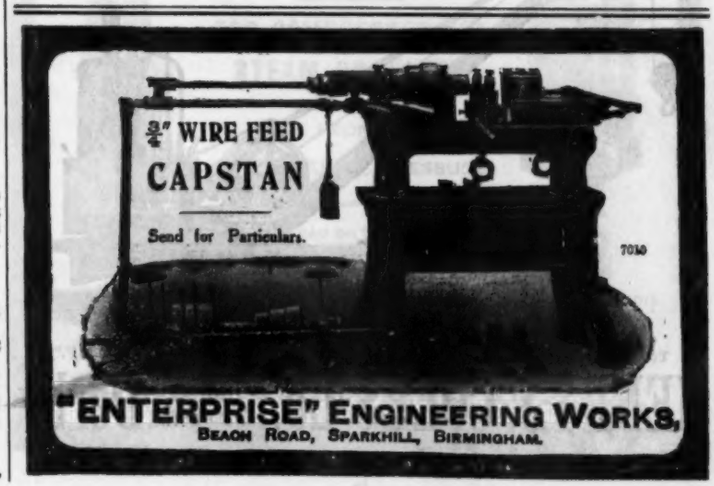

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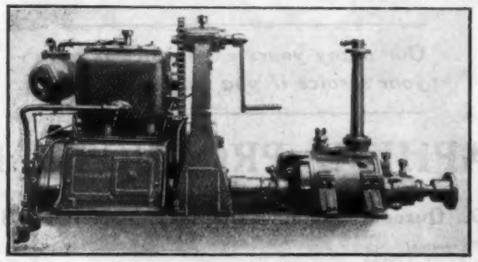

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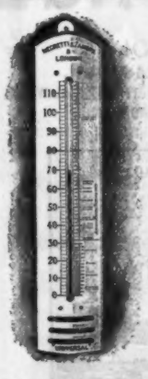

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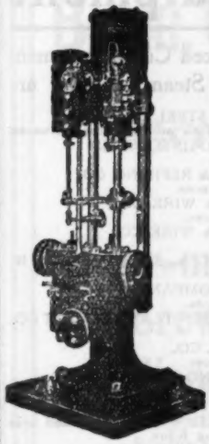

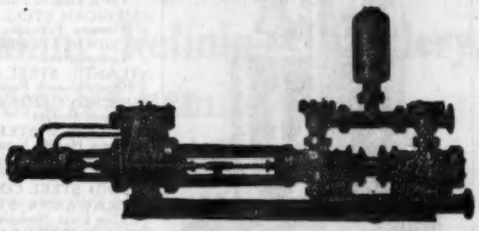

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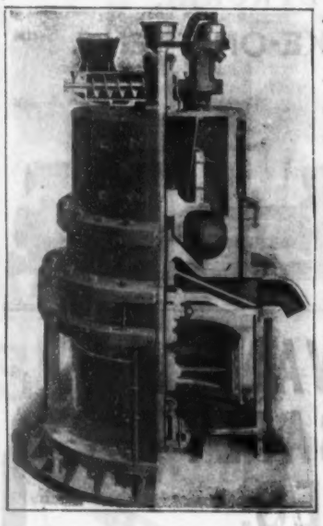

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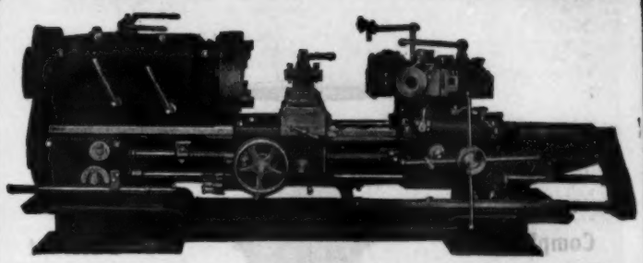

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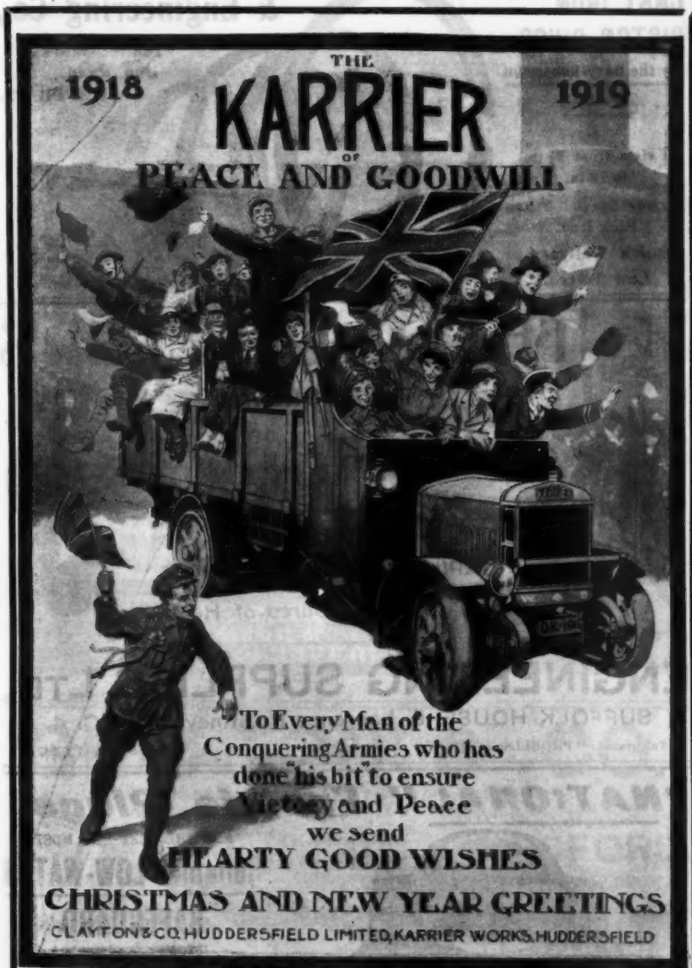

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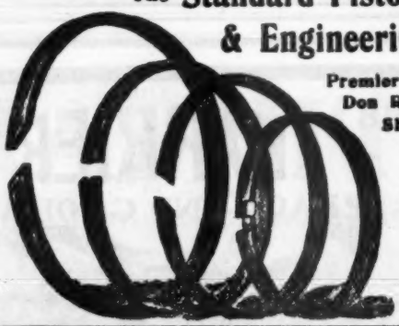

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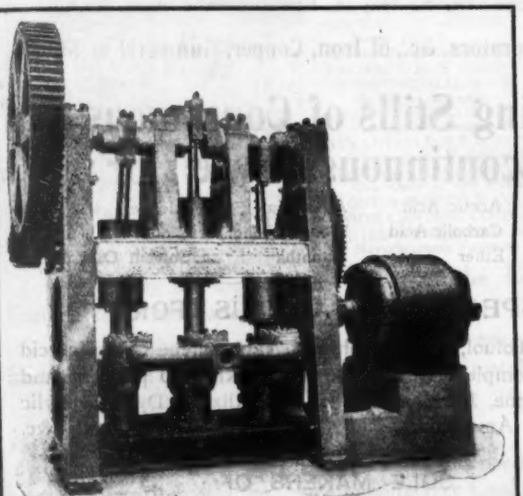

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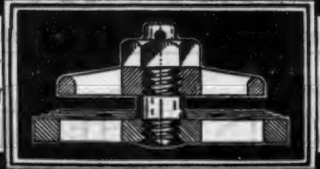

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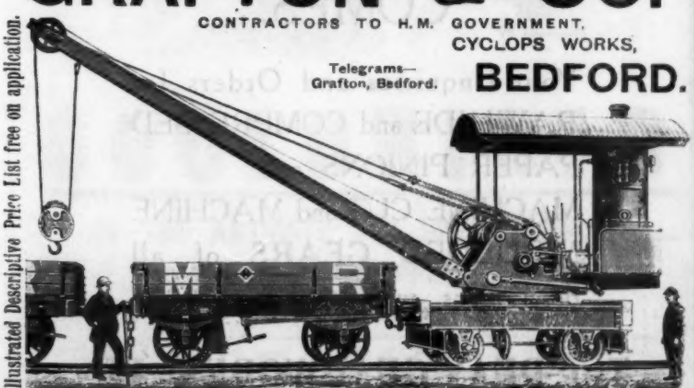

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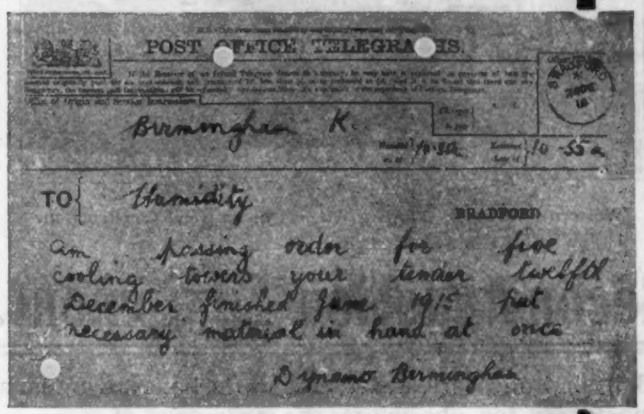
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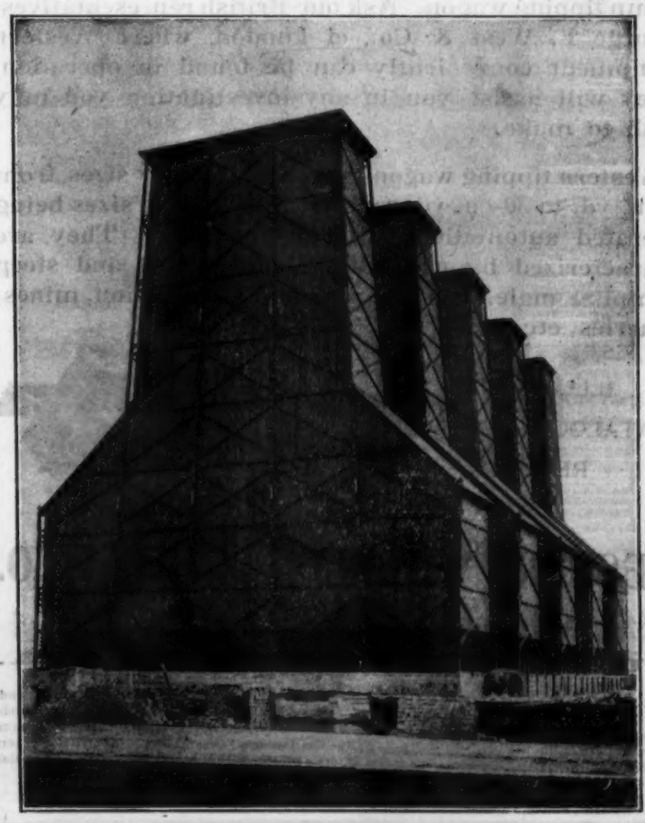

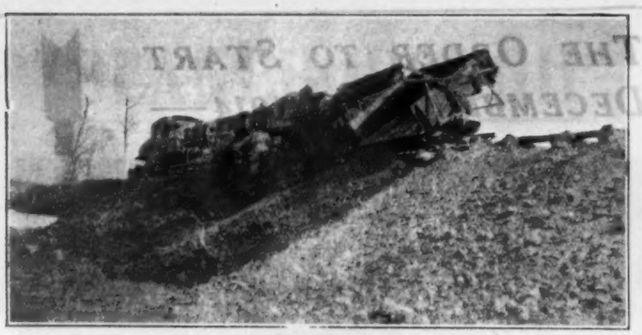

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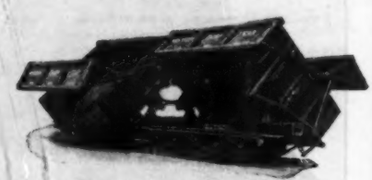

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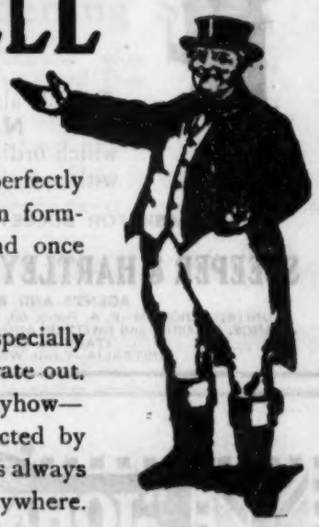

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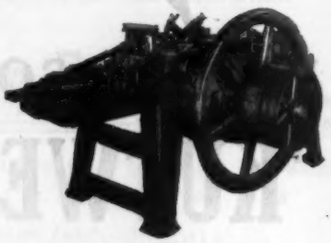

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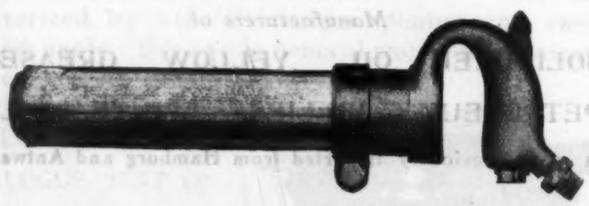

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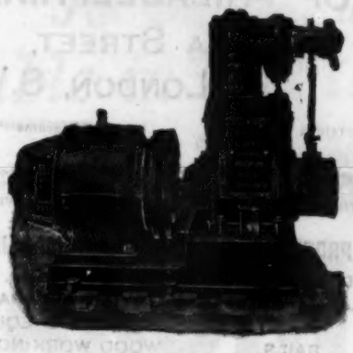
SIMPLE.  COMPOUND.

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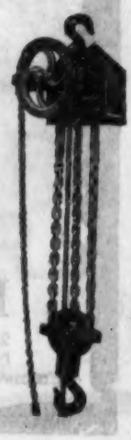

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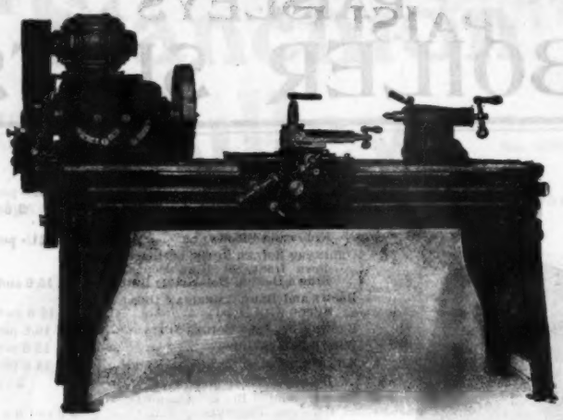

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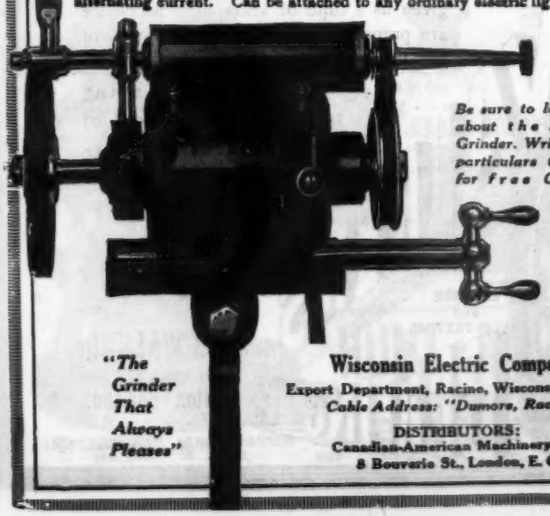

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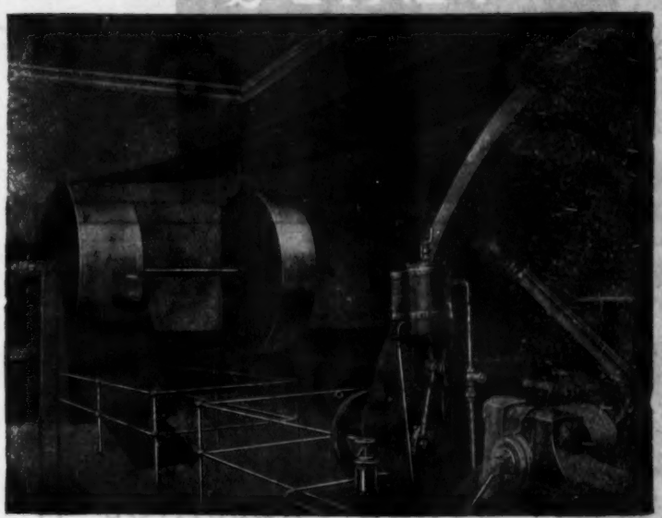

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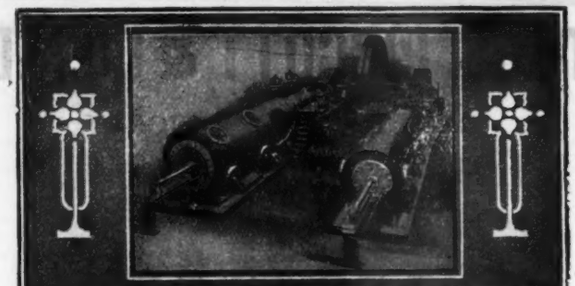

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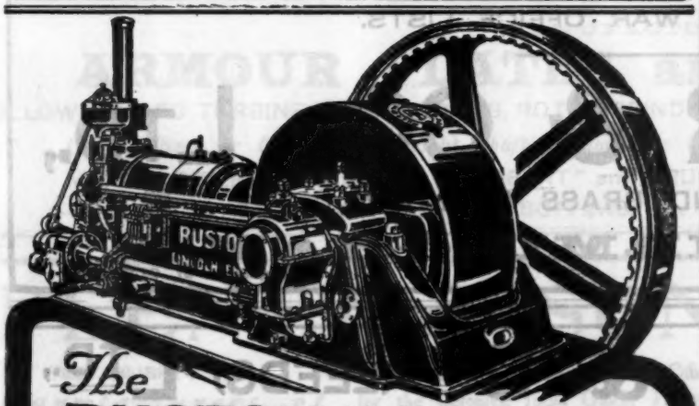

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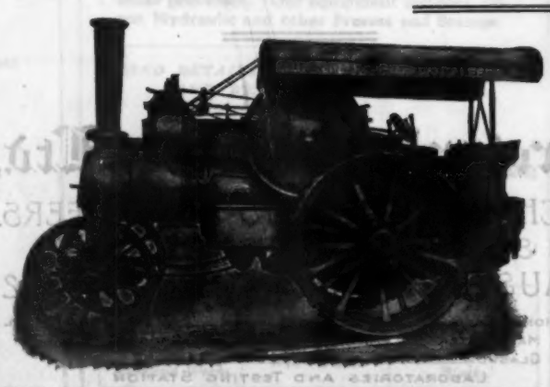

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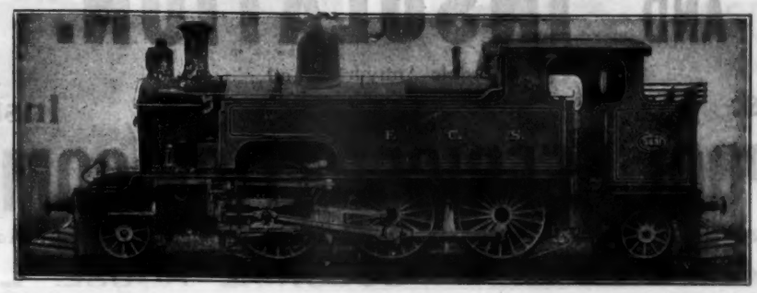

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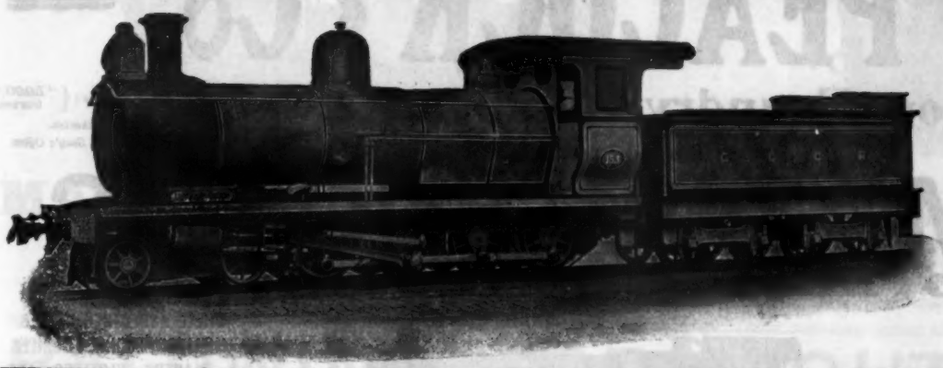

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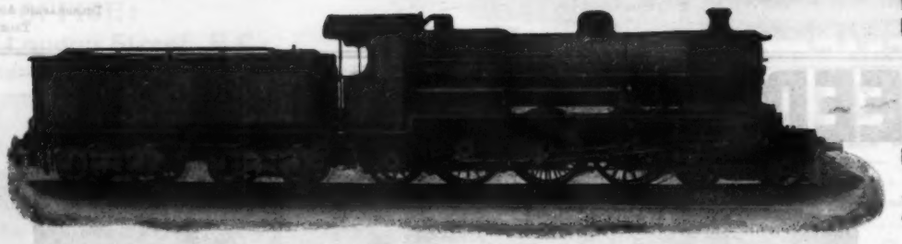

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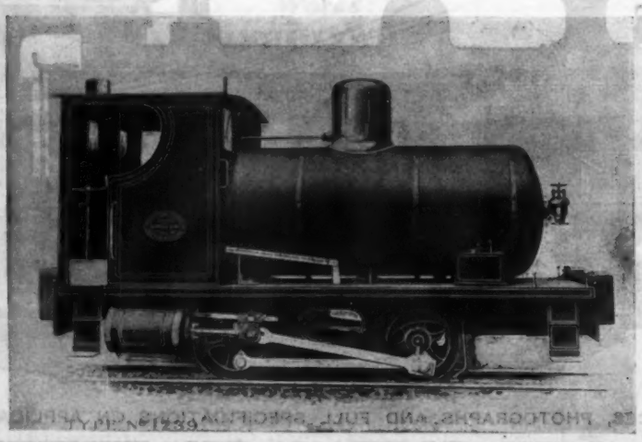

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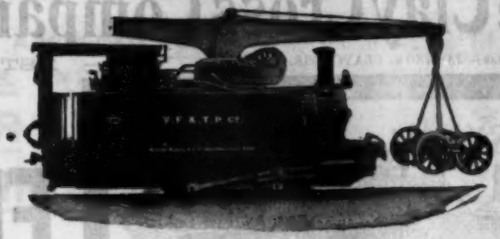

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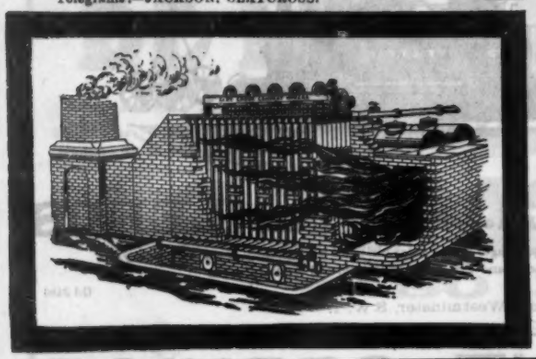

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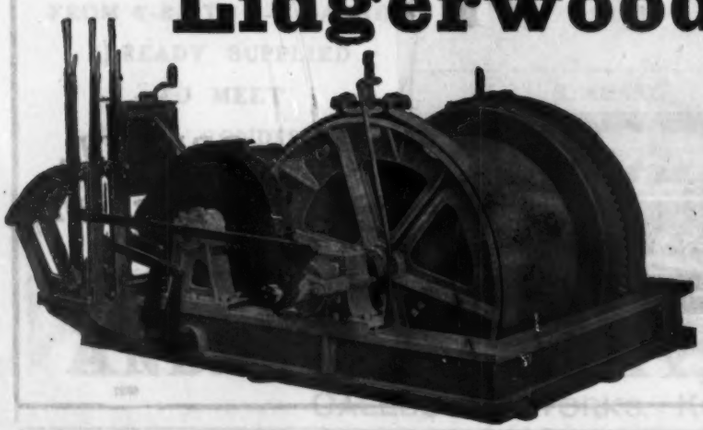

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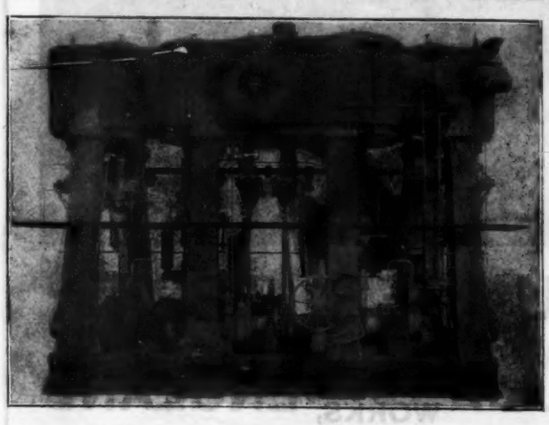

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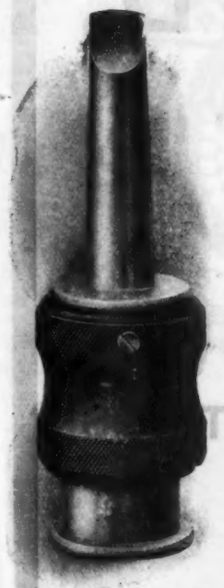

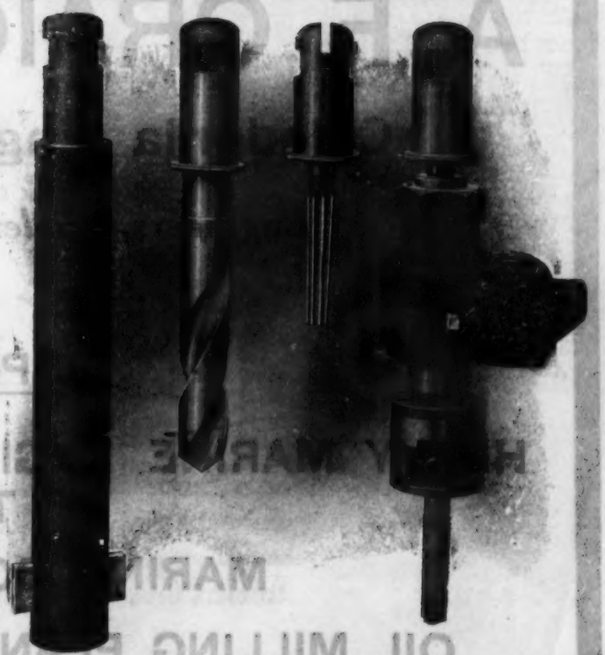

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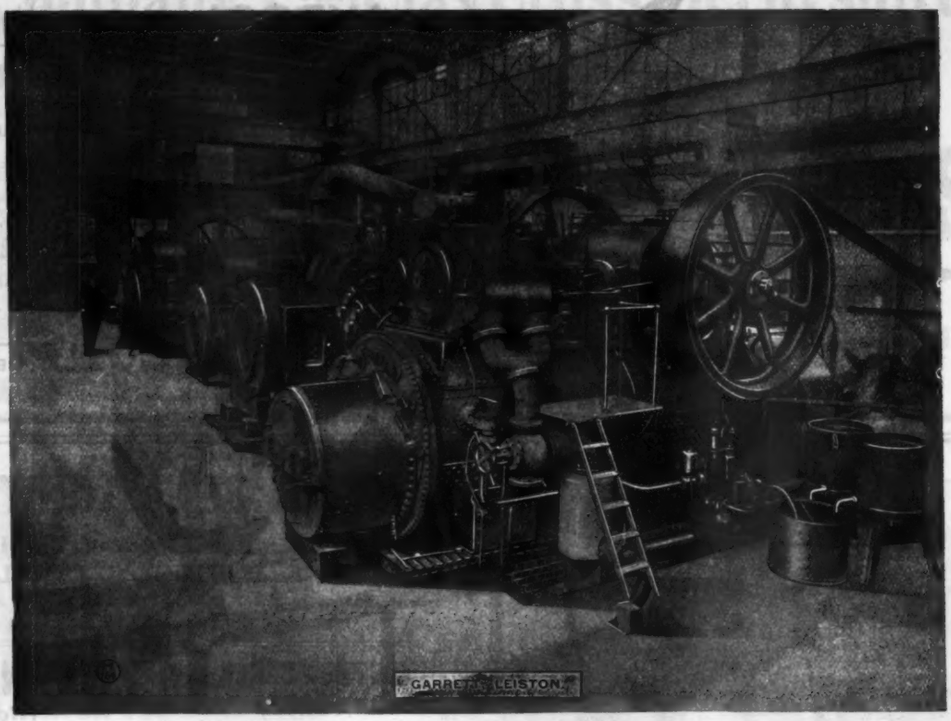

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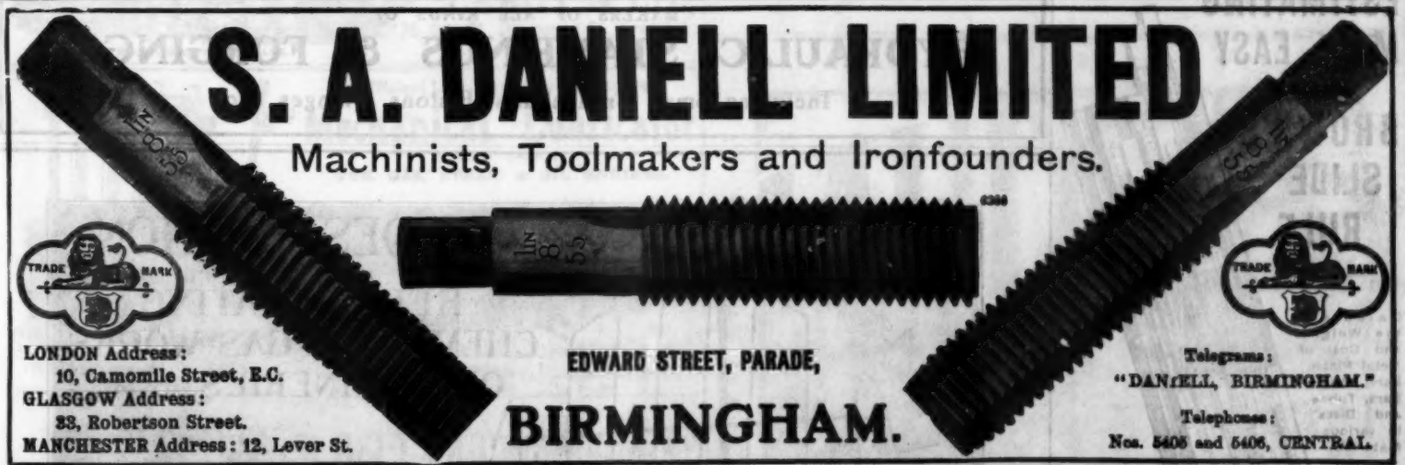

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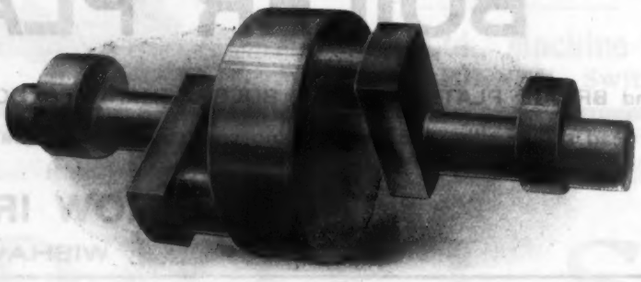

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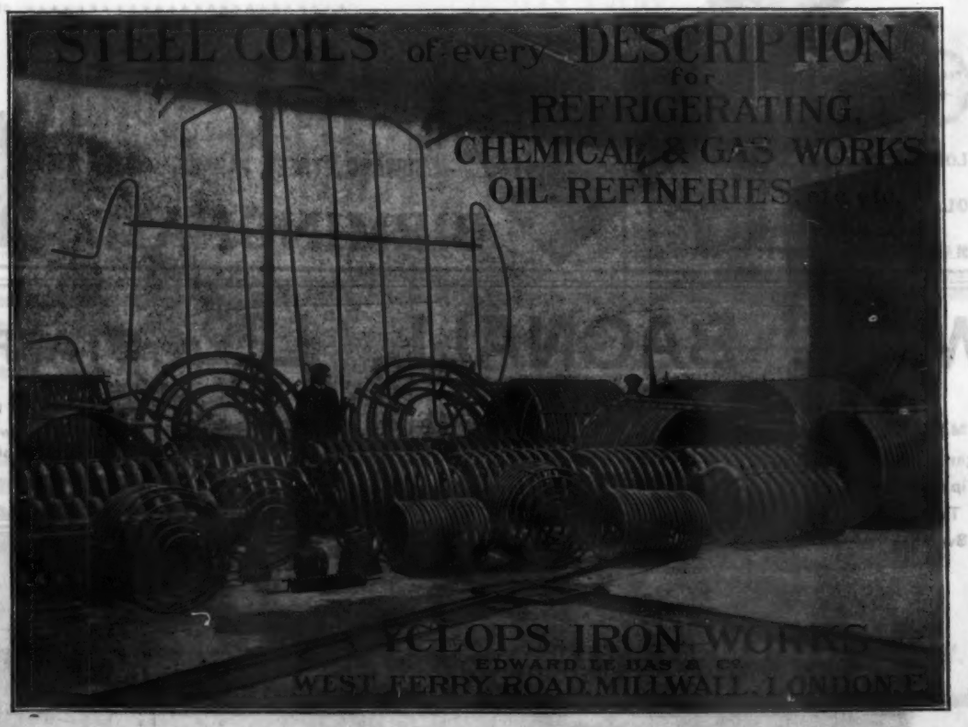

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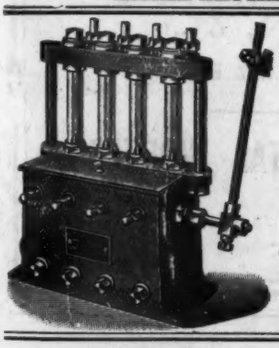

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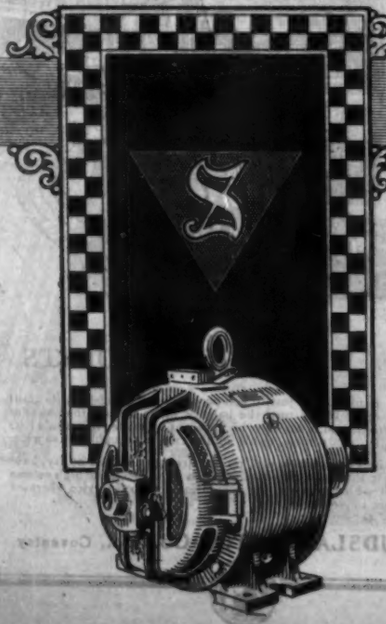

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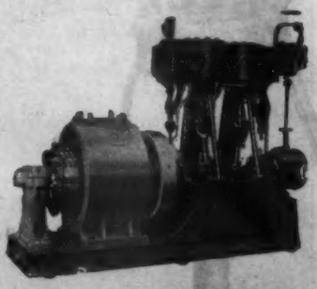

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Wanted, &c., continued on page 138.

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Exhaust Steam Turbine GENERATING SET. Direct coupled to E.C.C. Dynamo, 200 K.w., 440/500 volts, D.C., Condenser, motor-driven Circulating and Air Pumps, Switch Panels and Steam and Exhaust piping; forming a complete plant. Low price.
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Several 50 HP., Mechanical portions only, Double Drum Electric HAULAGE GEARS; rope capacity of each drum 1200 yards of 5/8 in. dia. rope.
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Also
One 30 in. by 30 in. Jeffrey Single-Roll CRUSHER or BREAKER, having a capacity of approximately 100 tons per hour.
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One practically new Mond GAS PRODUCER 1200 B.HP. continuously, for supplying Mond gas for driving gas engines and supplying gas for furnaces, complete with Coal Handling Plant. Available now.

Three 105 Kw. Hindley Vertical Five-cylinder GAS ENGINES, direct coupled to 500 volt D.C. Generating. Available now.

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Two 200 B.HP. 500 volt MOTORS, 290 revs., suitable for direct coupling to compressors.

One Compound wound GENERATOR, 310 amps., 240 volts, 540 r.p.m.

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Three "Eclipse" Compressed Air ROCK DRILLS, with Swivel Bars and Adjusting Screws.
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For Sale.—Powerful Vertical BORING MILL, by G. & A. Harvey, spindle 8 in. diameter, admits between standards 8 by 6 ft. 6 in. in height.
One Powerful 250 ton Vertical Hydraulic FORGING PRESS.
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One 48 in. Noble & Lund COLD IRON BAND SAWING MACHINE.
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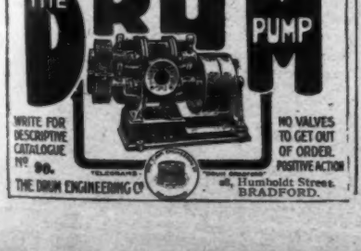
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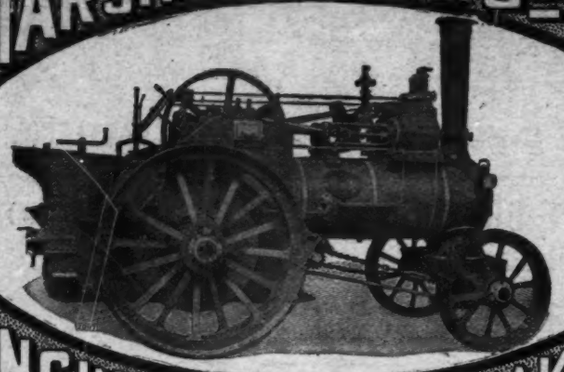

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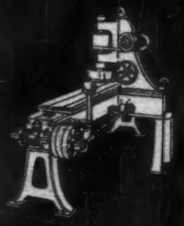

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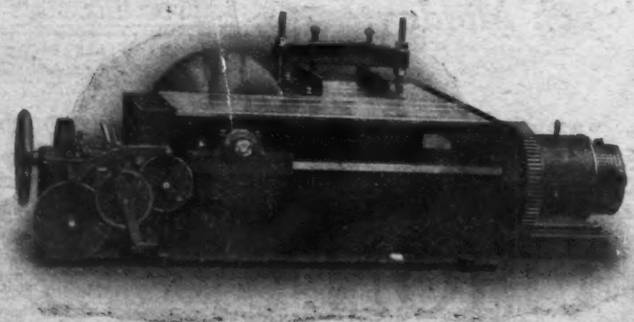

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